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Ionization control and particle size distribution of dust in swine buildings

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Ionization control and particle size distribution of dust in swine buildings

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INTRODUCTION

Over the past 20 years, much research has been done on the production of animals in confinement. As a result, improved manure-removal methods, ventilation design, and building arrangement combined with sound livestock management have made animal confinement a practical method for producing livestock. The number of swine confinement buildings in the United States has increased from 8700 new buildings built in 1963 to between 30,000 and 40,000 during 1973. The poultry industry showed similar building trends during the same ten-year period, with an increase from 8080 to an estimated 20,000 to 30,000. It is estimated that the agricultural building market may be on the order of 1.5 to 2 billion dollars annually (Ducker Research Company, Inc., 1974).

Well recognized is the contribution of dust and high humidity to the rapid deterioration of buildings and equipment. Dust is also a possible hazard to the animal and herdsmen. The particulate concentration in livestock buildings frequently exceeds the maximum 24-hour concentration set by the national primary ambient air-quality standards; and with the increased number and larger-sized facilities, more herdsmen are spending longer hours in this less-than-desirable atmosphere.

Dust serves as a carrier for bacteria, and the particle size determines the location within the lungs where a pathogenic organism is most apt to be deposited. It is estimated that 35 to 60 percent of all hogs marketed are infected with mycoplasmic pneumonia to the point that the rate of gain has been affected.[1] The resulting cost to the producer is on the average of $2 per hog marketed.

This loss could be expected to decrease considerably if there was an elimination of stress due to the dust-laden atmosphere. For example, poultry have been found to be free of respiratory diseases when produced in a dust-free atmosphere.

Dust is also a transport mechanism for odors. Some recent studies (McJilton et al., 1973) have shown that dust and gases add to respiratory system stress when accompanied by high humidity. Dust, odors and high humidity traditionally determine the winter ventilation rates. Thus by lowering these constituents, the ventilation rate can be decreased to conserve heat in the building.

At the present time, there is no air-filter system on the commercial market that cleans the atmosphere within a cost range acceptable to producers. Yet for the reasons outlined above, there is a real need for a dust-control system in livestock buildings.

To design an air-filter system, both the quantity of dust and the particle size are parameters that need to be known.

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[1]Switzer, W. P. 1974. Personal communication. Department of Veterinary Medicine, Iowa State University. Ames.

However, currently available dust data are generally reported in mg/ft^3 only, i.e., they do not include any size classification information.

The primary purposes of this research project are, therefore, to determine the quantity and the particle size of dust that is typical of different swine confinement systems; and to examine ionization as a possible method to control the dust in swine buildings.

The research data from this project should allow animal scientists and veterinarians to study in a laboratory situation the effect of dust typically found in swine buildings. It should also enable engineers to more intelligently design environmental-control systems for livestock buildings.

The use of ionization should demonstrate how dust particles can be charged, directed, and collected on designated surfaces for final disposal. The scope of this work does not include the optimum arrangement and charge on the charging electrodes, however, or the best arrangement of the collector plates with respect to air current.

LITERATURE REVIEW

Air pollution might be defined as the presence of a substance in the ambient atmosphere to the extent that it alters the quality of the atmosphere enough to cause harm to an individual or to a segment of society. Pollution can either be from natural or man-made causes. It can be a national or a localized problem. Nature has a way of protecting itself by balances; but when man adds excessive pollutants to the air nature cannot always provide the necessary balances.

The national primary ambient air quality standards recognize air pollution problems by placing maximum concentrations for an annual geometric mean and for 24-hours, and for an 8-hour, a 3-hour, and a 1-hour concentration not to be exceeded more than once a year.

Recorded concern about air pollution dates back as early as the thirteenth century, when, during the reign of King Edward I (1272-1307), there was a protest from the nobility against the use of "sea" coal (Chambers, 1968). The quality of the atmosphere has only been generally recognized as an important variable during the last few decades, however, as the result of several disastrous episodes during this period that focused attention upon air pollution as a health problem.

Chemical pollution

It is well known and documented that air pollution, which includes particulates, can cause acute respiratory disorders. Acute air-pollution episodes have always occurred under extraordinary meteorological conditions that reduced the effective volume and density of air in which pollutants were diluted. Most episodes occurred under conditions where small water droplets were present, which indicates that both aerosols and gaseous pollutants were involved.

On October 26, 1948, in Donora, Pennsylvania, 43 percent of the 14,000 people living in the valley became ill during a pollution episode, and 20 deaths resulted. Autopsy examinations of the fatalities gave no specific findings (Goldsmith, 1968).

In London, during the December 1952 smog episode, a cattle show was in progress. Fifty-two of the 250 animals became seriously ill, with five dying and another nine having to be sacrificed. At the same time, cases of bronchitis and pneumonia climbed at the zoo. The primary air pollution contaminants were sulfur oxides, smoke (particulates from 0.1 to 1μ), and a high relative humidity (Flower, 1972).

In 1958 a series of unusual episodes of increased asthma attacks occurred in certain sections of New Orleans, Louisiana. Visits to Charity Hospital increased from an average of 25 per month to 200 per day. After some tests were made, it was believed that dust from a flour mill may have been involved; at least, particulate matter of certain size ranges had a high degree of correlation with the outbreak. Similar outbreaks of asthma occurred on the Minneapolis Campus of the University of Minnesota which is surrounded by storage and processing plants of the grain industry. Skin tests with grain dust from the grain industry in New Orleans showed similar reactions on students at the University of Minnesota as had the dust from the Minneapolis grain industry (Goldsmith, 1968).

Particulate deposition

The dust-catching mechanism of the upper respiratory system operates somewhat like a commercial viscous filter. The walls are moist causing dust particles to adhere. The hairs of the nose also catch some dust during respiration. As the particles become smaller, they behave more like gas, and their chances of being centrifuged out against the walls of the respiratory tract are virtually nil. Therefore these smaller particles penetrate into the lower respiratory tract, the depth of penetration into the respiratory tract dependent upon particle size (Drinker and Hatch, 1954).

Particles larger than 10μ are almost completely removed in the nasal passage, resulting in little probability of penetrating to the lungs. Removal in the upper respiratory area drops to essentially zero at 1μ. Dust removal is high in the pulmonary air spaces, being essentially 100 percent for particles 2μ and larger. The percent of inhaled particles which penetrate to, and are deposited in, the pulmonary air spaces is a maximum between 1 and 2μ. Larger particles are usually trapped higher in the respiratory tract (Hatch and Gross, 1964).

Aerial transmission of pathogens

Air pollution and its effect on man and animal has been mostly concerned with chemical pollutants; and minimal attention has been given to the potential of air as a vehicle for transmitting pathogens. Like chemical air pollution, aerial transmission of infectious diseases occurs in an ecological setting. The pathogenic process in respiratory diseases is usually initiated either by inhalation of infectious aerosols or merely by the deposition of the organism on the superficial respiratory mucous membrane.

Airborne microorganisms can occur in three different environmental associations, classified as: (1) dust particles, (2) droplets or aerosols, and (3) droplet nuclei.

Dust particles are generally large pieces of dried material, and may be of vegetable, mineral, or animal origin. Since bacteria are not usually found free in air, dust particles become a likely host. An important aspect to consider in dust contamination is the possible formation of spores by bacteria and molds; thus, the microorganisms can resist unfavorable conditions for long periods of time. An example of this type of contamination is where secretion leaves the mouth in the form of a droplet. This droplet falls on a surface and dries to particulate matter with the organism attached to the particle.

Droplets are formed and expelled into the air during laughing, coughing, speaking, and from excreted waste material which will most probably contain a large number of microbes. The size of these droplets determine the location or distance of travel. The residue of droplet nuclei that are formed in still air will settle out according to Stokes Law. Many microbiological pathogens can remain viable in droplets for days (Kingsley, 1967).

Respiratory discharges with particle sizes small enough to remain in atmospheric suspension for long periods of time constitute a means of true aerosol transmission of disease. This droplet nucleus is the primary mode of spreading many diseases. The infective potential of the aerosol is dependent on the concentration of the organism in the atmosphere and the ability of the aerosolized organism to survive dehydration and temperature changes. Maintenance of transmission potential of aerosols usually requires a confined atmosphere with minimal ventilation. Conditions favorable for aerosol transmission are found in poorly ventilated piggeries, dairy barns, and poultry houses (Kahrs, 1966).

The size of the dust particle plays the all important role as the carrier of the virus and bacteria. In order to establish disease, the virulent organism must be deposited in a critical location (appropriate to the disease) within the respiratory tract.

Virus of Essex 70, the velogenic strain of Newcastle disease which resulted in heavy poultry losses in England before the use of live virus vaccines, was found to be relatively aerostable; thus, it could be carried by wind. These infective vires had been detected in air samples collected about 70 yards downwind from the naturally infected broiler house. It was found that in highly infected poultry units, up to 10 infective particles per hour could be spred as wind-borne infections (Dawson et al., 1973).

By applying a filtered air under positive pressure (FAPP) to poultry houses, birds could be raised free of respiratory infections such as Newcastle disease and Infectious Bronchitis. These birds were also found free of Marek's disease. With environment controlled in this way, birds had a lower mortality rate and produced a better rate of gain (Anderson, 1972).

With regard to the collection of particles, most micro-organisms can be collected by electrostatic precipitation, because they usually exhibit polarity in an electric field. Hence, the device for electrostatic precipitation is usually put first in the chain of devices employed for the purification of air. Problems may arise, however, in highly contaminated conditions, when clumps of organisms or particles occur that do not exhibit any polarity at all, and consequently are not precipitated (Kingsley, 1967).

Synergistic effects

Many environmental scientists believe that particulate matter is the most important element being measured, even though no single material can be considered responsible for all adverse health effects of the urban population. Their reasoning is based on the relatively high degree of toxicity of particulate matter when combined with other pollutants (Morrow, 1972).

The role of an air pollutant as a predisposing influence was suggested in 1957 when guinea pigs, exposed to ozone, had increased cases of pneumonia. Similarly, researchers have observed an increased mortality in mice from both streptococcus and klebsiella infections of the lung, when the exposure of the bacterial aerosol was preceded or followed by exposure to NO_2 (Coffin, 1972).

The pulmonary flow resistance of a guinea pig was reduced by 50 percent when exposed to a combination of particulates (1 mg/m^3 of particles with peak particle count occurring at 0.1μ), sulfur dioxide (1 ppm), and a high relative humidity (>80 percent). Little effect on pulmonary flow resistance resulted when any one of the three items was removed (McJilton et al., 1973).

Building deterioration and losses

Dust accumulation has been looked upon primarily as a nuisance rather than an added operating cost. These accumulations appear on ledges, electrical fixtures, exposed water pipes, and exposed structural components. A common and often costly result of dust build-up is in the ventilation system. Items such as fan motors, thermostats, timers and other ventilation controls become less reliable or have to be replaced frequently due to malfunctions caused by dust. With high-density housing, the failure of controls at an inopportune time can result in animal losses. If the ventilation system fails in modern windowless poultry houses, the oxygen supply may be depleted within thirty minutes (Rock, 1971).

Dust surrounding electrical fixtures can be the cause of fire. Several fires have been traced directly to electrical causes; for example, sparks from motors, fuses, switches, short-circuits and from the breaking of incandescent light bulbs. A number of fires have resulted from dust accumulating on electric light bulbs.

A report concerning a Minnesota turkey confinement building revealed the potential hazard that may develop from cleaning a building with a solution of water, cleaning compounds, and bacteria-killing agents. The electricity was shut off during the washing. After washing the building, the electric circuit at junction boxes was tested. The test showed zero resistance between the ungrounded conductors and ground. Inspection of junction boxes revealed them to be partially filled with a mushy wet material around the wires, inside the wire nuts, and around the inside metal boxes. Ten days later, the same electrical circuits were tested. At this time, there was maximum resistance on the circuit conductors. The junction boxes were dry and the foreign material was dry and caked.

Dust can be both an electrical conductor and a combustible. When electricity is restored to the building, electricity may travel from the wire connectors through the moistened material producing a low voltage arc. If the dust in the junction boxes is combustible, a fire may be started. In fact, the majority of the fires in poultry buildings have occurred after the building is emptied of birds, washed out inside, and ready to be put back into use. It appears that the fire hazard is greatest during the drying out period of the building (Nabben, 1973).

From one-third to one-half of the fires in Iowa where losses were greater than 25,000 dollars are attributed to defective wiring, dust, or a combination of both. These losses totaled to 760,000 dollars in 1971 (Office of State Fire Marshal, 1971) and 489,000 dollars in 1972 (Office of

State Fire Marshal, 1972).

Particulate matter is an important contributor to the corrosion of metals. Experiments at the Chemical Research Laboratory, Teddington, England, have shown that the rate at which iron rusts is greatly accelerated in a moist atmosphere containing sulfur dioxide with particulates present. In one experiment, a specimen of iron was exposed in a muslin cage which permitted air and sulfur dioxide to come in contact, but excluded particulates; its rate of rusting was negligible compared to a specimen outside the cage (Meetham, 1956).

Odors

Odors from swine buildings were found to be attached to moist, solid particles in the atmosphere. The odorous gases found to be associated with these air-borne particles were identified as organic sulfurs, and ammonia. Other nonodorous gases measured were carbon dioxide and methane. No quantitative analysis was made to determine the amount of these gases present (Day et al., 1965).

Particulate matter collected by high-volume samplings of a commercial poultry-house atmosphere revealed that particulates carried a "chicken-house" odor (Burnett, 1968). It was not determined, however, how a reduction in dust concentration will affect odor level.

Other reports have shown that the odors coming from a poultry house through exhaust systems were intimately associated with the particulate matter. Filter pads containing impacted poultry dust that were sealed up in plastic for six weeks still retained a strong and distinct odor (Eby and Willson, 1969).

Air ionization

Ionization of the air and its physiological effects have been the subject of much controversial research. Ions are present in the atmosphere in concentrations from 1000 to 2000 per cm^3. This is about 1 ion in 10^{12} molecules (Strauss, 1966). Several papers have been written, including some on the effect of ions on swine and poultry. The reported results are varied.

A study at the University of Georgia using negative air ions conducted tests of 30 days duration. No differences were found in activity, in rate of gain, or feed conversion of the pigs during the trial (Brown and Stone, 1965).

Another study, using both swine and poultry, showed conflicting results. Three tests on the effect of ion polarity on the rate of gain of swine indicated no effect. One test indicated that an excess of positive ions was harmful. Negative ions were found beneficial in one test and harmful in another. In still other tests, weight gains were better with both positive and negative ions than with natural conditions. The differences in rate of gain were great enough in some tests that the possibility of some effect due to ion polarity cannot be entirely dismissed, however.

Similar tests with 50-60 bird groups of Japanese quail also gave varied results. Six trials were conducted in which environments of different ion polarity were provided from one day to 28 days of age; in all but one trial, body weights were found to be less for the negative ion group than for either positive or "natural" ion group (Dobie et al., 1966).

Methods of control

There are several techniques available for reducing air-borne dust (Nutting, 1963), but most will not handle the volume of dust at an acceptable cost for confinement animal production. To select the best method for dust control in confined housing, the quantity of dust to be removed and the particle-size distribution must first be known. Prior to the research outlined in this project, these data were not available.

Two general approaches to dust control are feasible. The first of these is the reduction or elimination of the dust-producing source. In a swine system, for example, the source can be partly controlled by using pelleted feed or by wetting the feed.

Once a dust particle is air-borne, it tends to follow air currents, unless greater forces remove the particle from the airstream. Therefore, control of the air movement produced by ventilation is effective and tends to be the most practical means of dust removal when, as commonly practiced in mild or warm weather, ventilation is used for temperature control. During winter operation in colder climates, rapid exchange of the air by ventilation requires too much energy to be practical; thus, other means of dust removal must be considered. Commercial methods that may be considered are:

<u>Settling chamber</u> The simplest method of removing dust particles from a building is to allow the dust to settle out by gravity. By using Stokes Law, the maximum velocities that permit settling of 6μ and 10μ particles are 0.2 ft/min and 0.6 ft/min, respectively; therefore, practically all particles smaller than 10μ will stay in suspension. Particles larger than 10μ settle out rather rapidly, however, and require little other means of removal.

<u>Centrifugal "cyclone" separators</u> Though commonly used in industry, centrifugal separators will not remove the undesirable size range of particles found in animal buildings. The commercial cyclone separator is only effective in collecting particles larger than 10μ.

<u>Aerodynamic capture</u> The collection of particles by fibrous filters and liquid scrubbers is essentially the capturing of particles on the filter material. The fibrous filter can remove particles in the submicron range, but the expense of cleaning or replacement limits its use. Consequently, the fibrous-filter method is restricted to applications where the air to be filtered is relatively clean. Some

types of baffle-spray systems have been used in poultry houses where the temperatures are above freezing, but these are only effective in collecting particles larger than 10μ.

Electrostatic precipitation A dust-removal method gaining in popularity is the use of a corona discharge. Small water droplets and other particles in the air become charged by gas ions formed by an electrical breakdown in gases surrounding the high-tension electrode and then drift toward collector electrodes. The drift is toward any surface having an opposite polarity to that of the high-tension electrode.

Corona formation

The corona formation occurs when an electrical potential is increased between two electrodes to a level where electrical breakdown occurs. For two parallel plates in ambient air, the critical value is about 30 kV/cm of separation between the plates. If a fine wire or point is used for the charging electrode, breakdown can occur near the charging electrode without a passive electrode located nearby. This occurs at charge potentials as low as 6 to 8 kV, depending on the size of the fine wire or needle point. Because an a.c. corona causes an oscillation motion of the charged particles and whereas a d.c. voltage does not, the latter is always used.

There are two types of corona discharges; i.e., the charged electrode is either positive or negative with respect to the passive electrode.

Negative corona The normal atmosphere contains about 1000 to 2000 ionized particles per cm^3. When the current is flowing, additional ionized molecules are formed from the ultraviolet radiation in the corona glow region. These gases have a positive charge and move toward the charging electrode, producing even more free electrons and positive ions by molecular impact. The electrons and negatively charged ions are repelled and accelerated by the strong electrical field around the negative electrode. The speed of the electrons and negative ions decreases as the distance from the charging electrode increases. The only ionization that occurs outside of the corona-glow region is with electronegative gases, usually oxygen. These gas ions then move toward the passive electrode with a speed proportional to their charge and the intensity of the electric field. It is in this region where the dust particles receive their negative charge (Oglesby and Nichols, 1970).

Positive corona The free electrons in the atmosphere move toward the discharge wire to maintain the corona region. The positive gas ions formed by molecular impact in the corona region move at much lower speeds than do the electrons in the negative-corona region, thus producing fewer ionizing collisions while moving toward the passive electrode (Strauss, 1966).

Particle charging

There are two basic methods for charging dust particles. The more important of these is when particles in an electrical field cause localized distortion of the field so that electric field lines intersect the dust particle. This is known as either bombardment or field-dependent charging. Ions present in the field tend to travel in the direction of maximum voltage gradient, i.e., following the electric field lines. Ions will intercept the particles where their paths cross, resulting in a charge being given to the particle. The dust particles continue to gain in charge until the charge on the dust particle is strong enough to divert the electric field lines to the extent that the field no longer intercepts the dust particle. At this point, the particle is said to be saturated and its charge will stabilize. The electrostatic theory of the process relates the magnitude of the electric field in the region where charging takes place, the particle size, and the dielectric constant of the particle. Since the saturation charge is proportional to the square of the particle diameter, larger particles are easier to collect than smaller ones (Strauss, 1966).

The time required for a particle to acquire a saturation charge depends on several factors but becomes asymptotic as the particle nears saturation. If only a single particle enters a high ion density field, charging to saturation will take place in milliseconds. However, under conditions of large dust loading and low currents, the time for charging to saturation can be appreciable.

The field-dependent charging mechanism is less important for small particles (<0.2μ diameter). These particles are primarily charged by diffusion; and the collision between the particles and gas ions are largely governed by the thermal motion of the ions. Since the range of thermal velocities has no upper boundary, there is no saturation value for these small dust particles. However, as the charge increases, the probability of impact decreases, thus decreasing the rate at which these small particles become charged.

Particle charging theory indicates several important factors governing collection performances. In field-dependent charging, the magnitude of the particle charge is dependent upon the electric field strength, i.e. field strength determines the force acting on the charged particle; thus it should be kept as high as practical. The rate of charging of the particle is also important since as the dust loading increases, the time to charge this dust to its saturation also increases.

The electric field strength is determined by the electrostatic components. This includes the precipitation geometry, the applied voltage, and the space-charge components. The design of the precipitator can alter the geometry of the discharge electrode and the spacing. Variation in electrode geometry can also alter the corona current, influencing the electric field.

The dust accumulation on the collection electrodes limits the maximum voltage and thereby the electric field strength at which the precipitator can operate. The voltage drop is dependent upon the corona current density, the electrical resistivity of the dust, and the thickness of the dust deposited on the collecting surface. For high resistivity dusts, the voltage drop across a thick collected dust layer can be as high as 10-20 kV.

Sparking is another condition associated with high dust resistivity that can also influence particulate charging. When this occurs, a crater is formed in the dust, and current densities in the area can produce a localized electric field sufficiently high enough to initiate a corona formation. This results in a positive ion production, that collide with the collected dust particles and an opposite polarity to that required for collection (Oglesby and Nichols, 1970).

Particle collection

The forces acting on a charged particle in the atmosphere are gravitational, inertial, electrical, thermal, and aerodynamic. The major forces acting on these particles are dependent on the size of particles, field charge, and the air velocity. If a particle is carried by an air stream inside a chamber, a force due to the electric field and particulate charge will act on the particle in the direction of the collection electrode. The larger of the forces acting on a particle is dependent upon the size of particle, and the velocity of the air. The motion of the particle will be along the line defined by the vector sum of the forces; however, at the boundary layer of the collecting surface the gas flow is laminar and particles entering the boundary layer will be collected.

Removal

Once collected, the dust or liquid aerosol should be removed from the precipitator. This can be accomplished by flowing water down the collecting surface, or vibrating the electrode so as to mechanically dislodge the dust. Liquid aerosols collected will normally drain from the collecting surface thus their removal is not usually a problem.

System analysis

The interaction of the several involved variables makes it difficult to analyze the performance of a precipitator, because defining the electric field gradient in a room is nearly impossible. The interaction of each parameter can not be readily defined in terms of simple mathematical model, thus requiring a physical model for evaluating the system.

ANIMAL EXPERIMENT

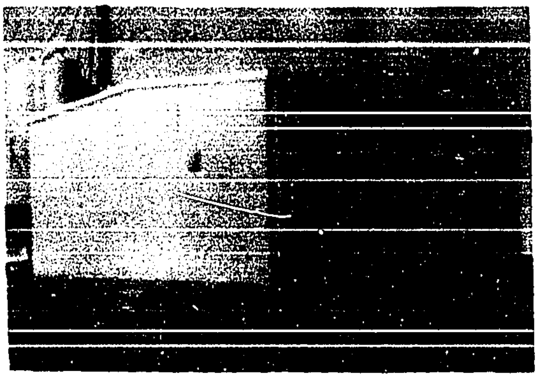
The animal experiments were conducted to obtain a quantitative estimate of the dust concentration and the particle size distribution that might be typically encountered with conventional management and feeding methods. They were used to determine the effectiveness of ionization as a dust control measure.

Most of the dust studies with animals were conducted at the AISI-ISU swine atmospheric research building, a laboratory cooperatively supported by the American Iron and Steel Institute and Iowa State University. The laboratory is located at the Swine Nutrition Station. The remainder of the data were obtained from farrowing building #5 at the Bilsland Swine Breeding Station, Madrid, Iowa.

AISI building

The AISI laboratory (Fig. 1) is a rigid-frame building, 42 ft long by 30 ft wide. Exterior siding, roofing, interior walls, and ceiling surfaces are of ribbed vinyl coated steel panels. All exterior and interior walls, and ceiling and roofing panels are insulated. The building houses two animal chambers, an air-mixing chamber, a mechanical and feed room, and a laboratory (Fig. 2). Each animal chamber is 19.5 ft long, 14.3 ft wide and 8 ft high with 3 pens which are 15 ft long and 4 ft wide. The two chambers are separated by a 12 ft wide hallway.

Figure 1. Exterior view of the AISI building, chamber #1 with concrete floors and solid concrete partitions, and chamber #2 with stainless steel slatted floors and steel pen dividers, respectively



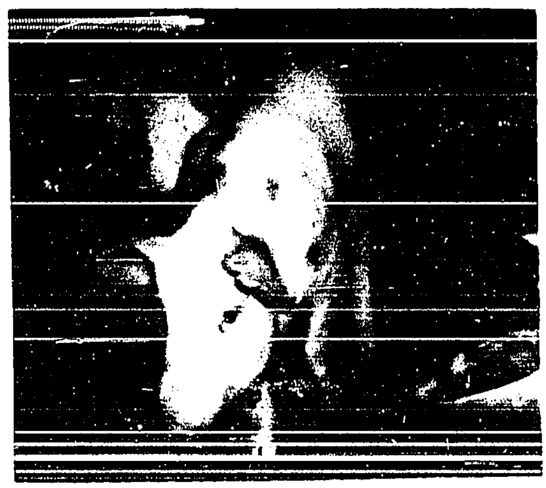
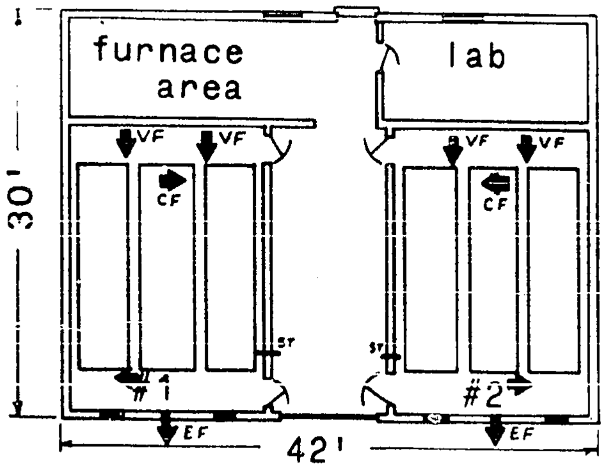


Figure 2. AISI building floor plan with the direction shown by an arrow and type of air movement shown by VF, CF, and EF indicating ventilation fan, circulating fan, and exhaust fan, respectively

Figure 3. Isometric of AISI building showing heating and air conditioning system


furnace area
lab
VF
VF
VF
VF
CF
CF
ST
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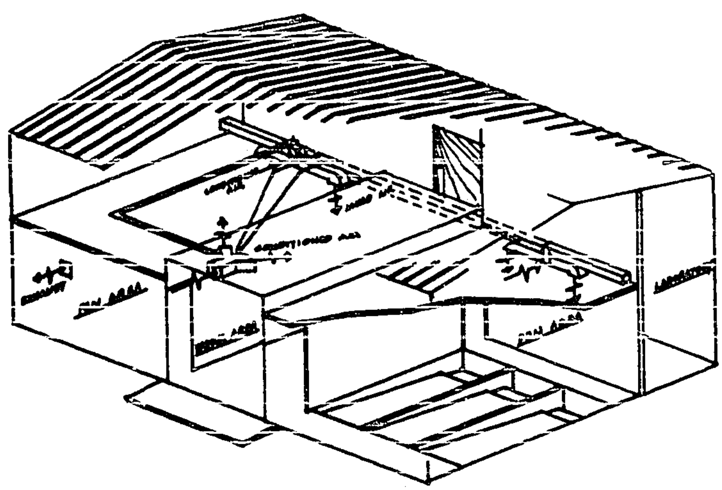
#1
#2
EF
EF
30'
42'



Flooring

Removal of the slatted-floor sections in chamber #1 permitted the chamber to be used as a sloping, solid-floor system for floor feeding, the upper, or dry, portion of the solid floor is 11.25 ft long, and slopes at 0.5 in. per foot to a 0.3 ft stepdown which separates it from the 3.4 ft long lower, or dunging area, portion that drains into a narrow gutter. Tipping buckets are normally used to flush the dunging area but for the ionization studies, the tipping buckets were removed to prevent interference between the bucket and the charging electrode. Thus, the dunging area had to be hosed daily.

Chamber #2 has a stainless steel slatted floor with flushing under the slats. The pen dividers, also of stainless steel pipe, increase the size of each pen over those in chamber #1 by 0.5 ft in both length and width.

Ventilating system

The ventilating system (Fig. 3) for providing constant-temperature air to the chambers contains two heat exchangers in the air plenum above the chambers for heating; two cooling coils in the cold air ducts, an air reservoir or plenum, a thermostat controlled modulating damper complex and a variable speed control of the two ventilation fans in each chamber. The damper complexes are located in the supply air ducts and controls the ratio of the heated air drawn from the plenum and cold air from the outside. The air leaves the chamber through an exhaust fan and two 1 ft by 2 ft exhaust openings located opposite the intake fans.

Animal management

Eight pigs, each weighing approximately sixty pounds, were put in each pen for a total of 24 pigs per chamber. The pigs remained on the experiment for approximately 4 months. The pigs used for all experiments were a four-way cross: Yorkshire, Landrace, Hampshire, and Poland China.

Methods of feeding

The method of feeding was varied in the experiments. Animals in chamber #1 (with solid floors) were floor-fed or fed wetted ground feed twice daily in a trough. Self-feeders were tried on the concrete floors, but the animals dunging habits prevented continuing this practice.

Animals in chamber #2 (with slatted floors) were fed in self-feeders or fed twice daily in troughs according to the experimental design.

Ration

Twelve and fourteen percent protein corn-soybean meal rations were used for the experiments. The protein level varied with the availability and cost of soybean meal. The studies relating to average daily dust concentrations were compared by days using the same ration. Three forms of feed, all ground through a 0.375 inch screen, were used in the experiments either as ground, ground-wetted, or pelleted.

Chamber ionization

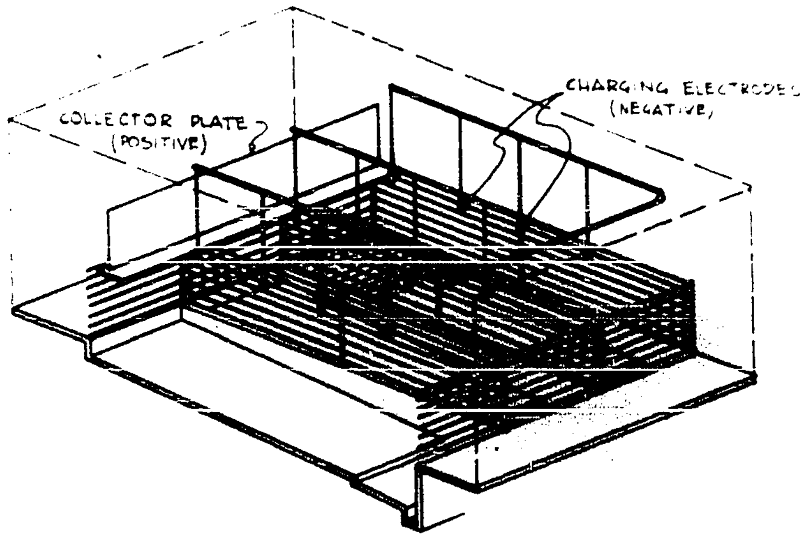
The air was ionized by using negatively charged needle points located approximately 4 ft above the floor of the pens. The charging potential was 115 V transformed, by an a.c. to d.c. converters, to approximately 12 kV. The charged needle points were located in a rectangular grid pattern over the pens (Fig. 4) and an aluminum collector plate, 14 ft long and 2.5 ft high, was located in the exhaust end of the building in chamber #1. The plate was mounted vertically (Fig. 5) 4.5 ft off the floor and 4 ft from the exhaust fan.

Discharge electrode The discharge electrodes (Fig. 6) were made from common sewing pins soldered to 40 kV cathode ray wire that was in turn connected to the power supply. A plexiglass rod, 1.5 in. diameter and 1 in. long, with a hole drilled longitudinally through its center, was used to shield the head. A metal weight was placed on top of each head to straighten the wire and hold the needle point in a vertical position. The rod was placed over the soldered connection with 0.5 in. of the needle point protruding from the plexiglass cover. All splices and connections were soldered, sanded, and taped to reduce the current drain in the system.

Power supplies Two power supplies were used for the ionization system; one for the discharge electrode, and the other for the passive electrode (collector plate). The dis-

Figure 4. An isometric of chamber #1 showing the 12 charging electrodes and collector plate

Figure 5. A cross-section of chamber #1 showing location of ionization equipment


COLLECTOR PLATE
(POSITIVE)
CHARGING ELECTRODES
(NEGATIVE)

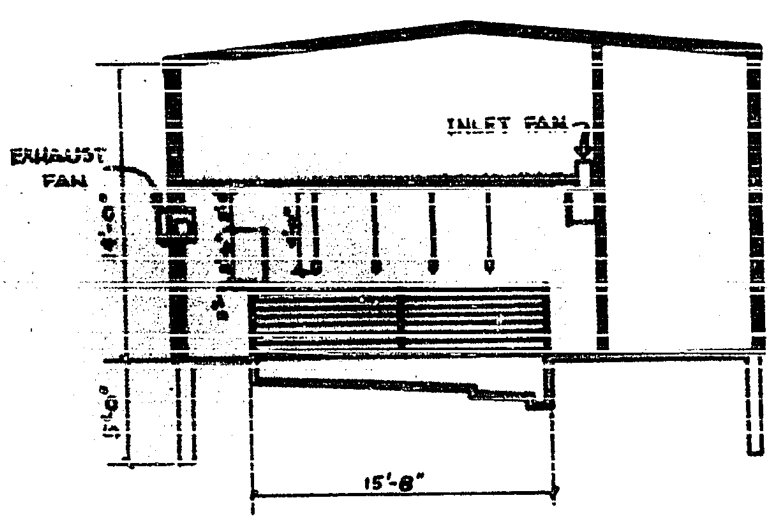

INLET FAN
EXHAUST
FAN
15'-8"

Figure 6. A cross-section of the charging electrode and a picture of charging electrode in front of metal collector plate

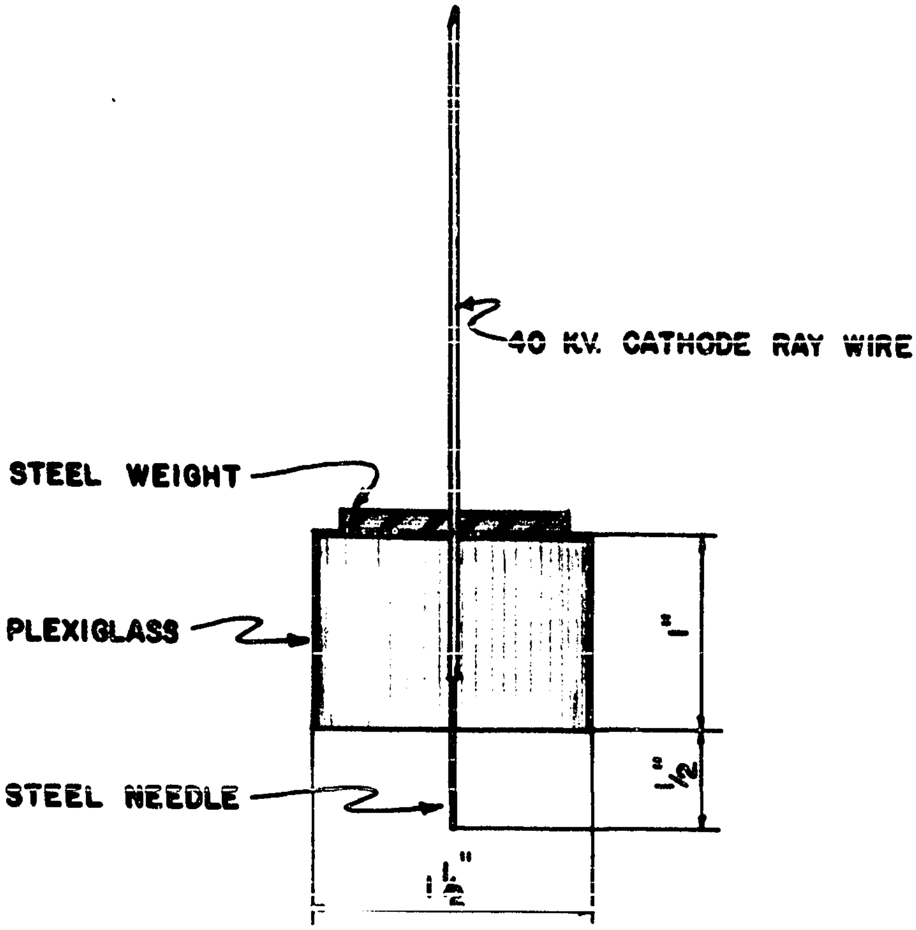
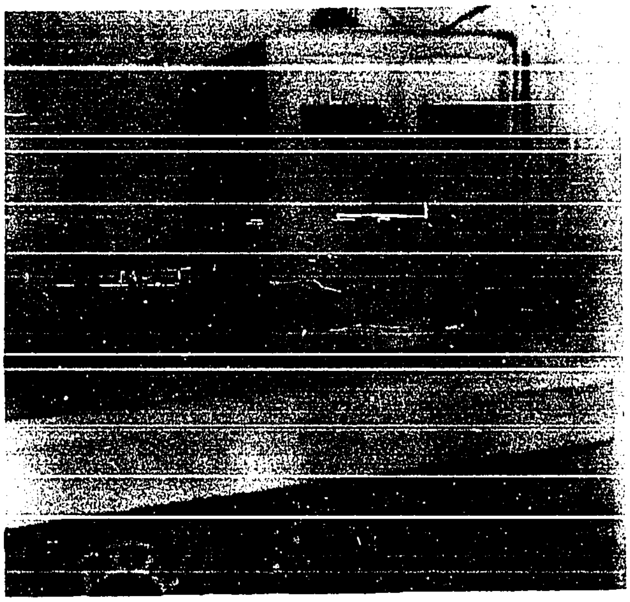

40 KV. CATHODE RAY WIRE
STEEL WEIGHT
PLEXIGLASS
STEEL NEEDLE
1 1/2"

Figure 7. Power supply connected to the charging electrode

Figure 8. Power supply connected to the collector plate



charge electrodes were connected to the power supply (Fig. 7) providing negative voltage of 12 kV with respect to ground and a current rating of 0.05 mA. A power supply (Fig. 8) with positive voltage of 8 kV with respect to ground and a current rating of 0.05 mA was connected to the collector plate.

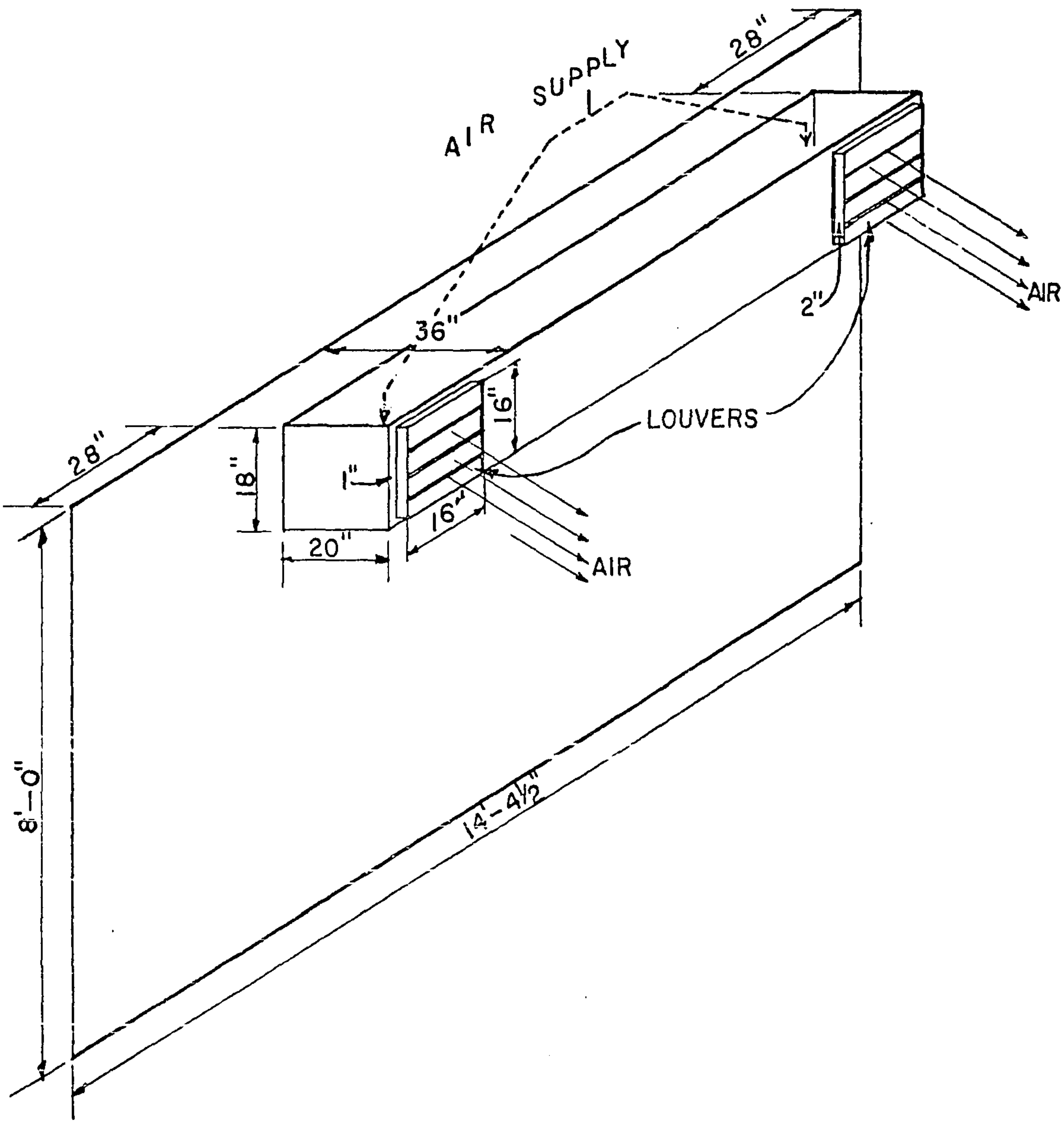
Ventilation and air circulation

The ventilation systems for the two chambers are identical. Conditioned air is supplied through an inlet duct and located on the south wall of each chamber (Fig. 9). A 12 in. 1/20 hp fan located in each duct and controlled by a variac, supplied 920 cfm of air into each chamber (Appendix A). Air flow was generally horizontal but with a slight downward deflection due to louvers in front of the fans.

To provide additional air mixing, two circulating fans were used in each chamber. These fans had a capacity of 3120 cfm and 3050 cfm of air in chamber #1 and chamber #2, respectively. In Figure 2, VF, EF, and CF designate the ventilation fans, exhaust fan and circulation fans, respectively. The arrow indicates the direction of flow.

The chambers were maintained at 70°F $\pm$ 5° throughout the testing. The relative humidity ranged from 40% to 85%, depending upon the ventilation rate.

Figure 9. South wall section of chamber showing location of conditioned air supply



AIR SUPPLY
28"
36"
28"
18"
1"
20"
16"
16"
AIR
2"
LOUVERS
AIR
8'–0"
14'-4½"

Bilsland facility

Farrowing building #5 is an insulated wood frame building with an interior and exterior plywood covering, a solid concrete floor, and metal roof. Sows are farrowed in a single row of stalls in this 24 ft by 128 ft building. Manure is removed by hydraulic flushing. At the time data were taken, the building was empty and had been recently cleaned and disinfected. During the sampling, all fans were off and the windows and doors closed.

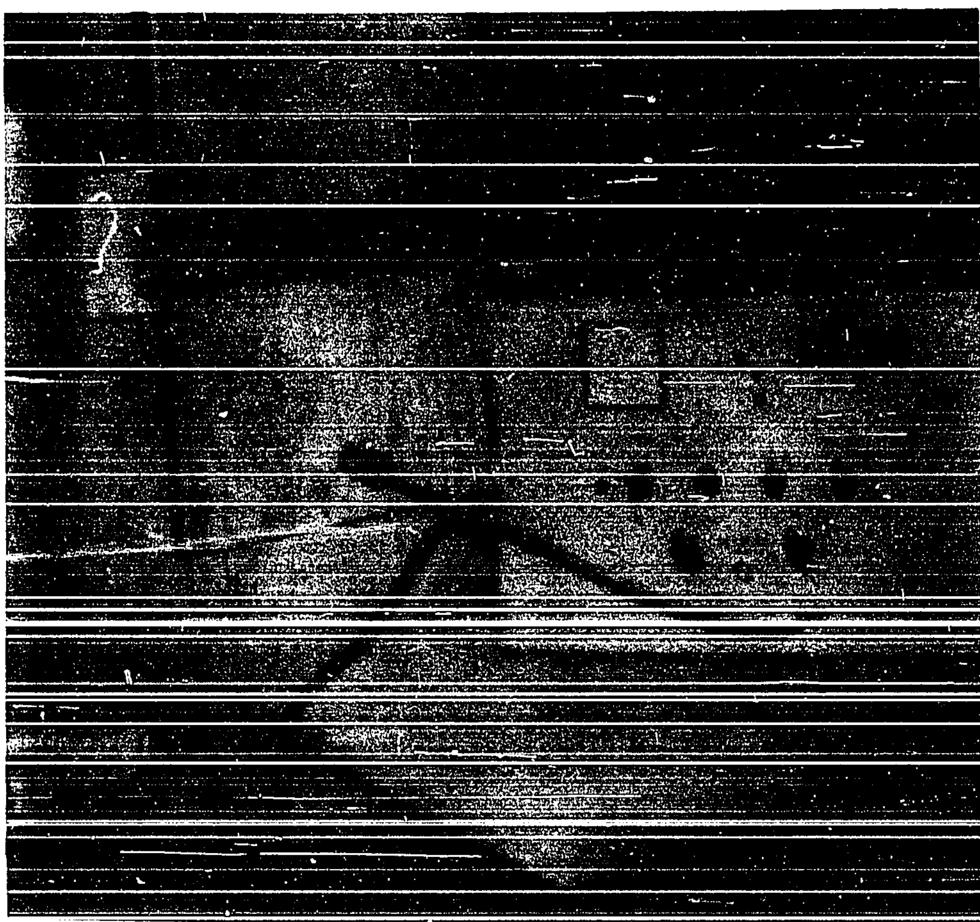
Procedures used in collecting data

The dust level of the outside air was measured 3 ft above the ground. Inside sampling, without animals, was measured at approximately 3 ft from a wall and at a height of approximately 3 ft above the floor. Care was taken not to stir up dust when entering an empty building or while setting-up the instrument. If animals occupied the chamber, the disturbance caused by a person entering the chamber required that the sampling technique be changed. Instead, samples were taken by quietly setting the instrument in the hallway and inserting a sampling tube through the wall into the chamber.

Sampling equipment

Dust concentrations were measured with a Royco Model 215 Portable Particle Counter (Fig. 10). Settings on this equipment are 0.5, 1.0, 2.0, 3.0, 5.0, and 10.0μ. The equipment

Figure 10. Royco Model 215 Portable Particle Counter



detects and counts particles of and larger than the indicated setting, i.e., 0.5μ diameter and larger, 1.0μ diameter and larger, 2μ diameter and larger, etc. The sizing of the particle is made by an optical detector mechanism. The sampling flowrate is 0.01 cu ft of gas per minute. Normally two one minute readings were taken and averaged. Moisture condensation in the sampling tube was the only problem encountered with the instrument and this occurred only when sampling air with a relative humidity greater than 92 percent.

RESULTS FROM ANIMAL EXPERIMENT

Dust concentration inside empty confinement buildings

Dust levels in empty confinement buildings were found to closely parallel the outside dust concentration. Figure 11 shows the comparison of the dust concentration in the two chambers at AISI and farrowing building #5 at Bilsland Swine Breeding Station with the outside dust concentration. Dust concentrations of particles 0.5μ, and greater, varied from approximately 200 to 3000 particles per 0.01 ft^3 with mean values of 866 and 830 for inside and outside the buildings, respectively. The plot shows that a good estimate of the inside dust level can be predicted from the outside dust count. The infiltration rate of dust in AISI, which is a very tightly constructed building with no outside doors leading directly into the chamber, was about the same as in farrowing building #5. Rain usually reduced the dust level in the air by as much as 50 to 75%. Inside data taken before and after a rain show that the infiltration rate is very rapid. These data also show that the base level can change by a magnitude of 80 to 90% and that it is not practical to try to control below this value by ventilation.

Dust concentration with floor-feeding for different ventilation rates

Dust concentration in chamber #1 was investigated with ventilation rates of 0 and 900 and at a 900 cfm ventilation

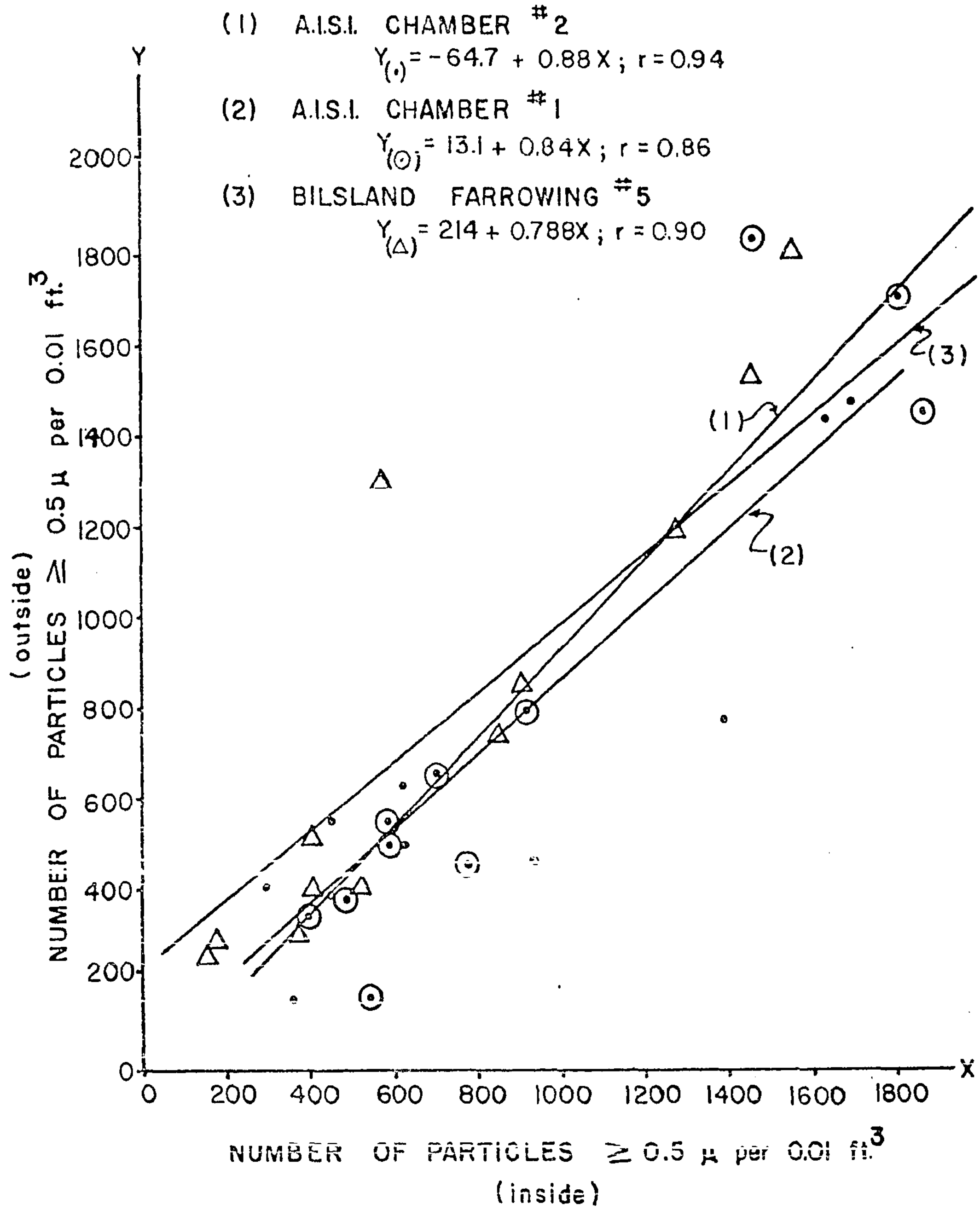


Figure 11. A comparison by least square curves of the dust concentration in empty confinement buildings (chamber #1, chamber #2, and Farrowing Building #5) with the dust concentration outside each of the buildings

rate with 3100 cfm of internal air circulation. In every case, the dust concentration was measured prior to feeding. The significance of ventilation with and without internal air circulation in reducing the dust level is shown in Table 1 for several particle-size ranges. The difference in treatment B and C was not significant for particles of 0.5μ diameter and larger.

Table 1. The effect of different ventilation rates on floor-feeding

Treatment[a]	Particle size (μ)	Mean	Variance	t-test	
				Treatments compared	Value
A	0.5	8076	6,191,591	A-B	5.81**
B	0.5	2362	1,560,693	B-C	NS[b]
C	0.5	3021	3,587,185	C-A	4.95**
A	2.0	2085	421,865	A-B	5.62**
B	2.0	636	122,496	B-C	2.10*
C	2.0	993	511,155	C-A	3.80**
A	5.0	193	8,265	A-B	2.29*
B	5.0	98	10,222	B-C	NS
C	5.0	124	14,809	C-A	NS

[a]Treatment A, B, and C refers to 0 cfm, 900 cfm, and 900 cfm ventilation with 3100 cfm air circulation, respectively.

[b]NS = not significant.

*Denotes significance ($p \leq 0.05$).

**Denotes significance ($p \leq 0.025$).

The number of particles 0.5μ, and larger, decreased with ventilation from 8076 particles to 2365 particles per 0.01 ft^3, approximately a 70 percent reduction. The ventilation effect diminishes as the particle size increases. With ventilation, the dust level decreases about 50 percent for 1μ, 2μ, and 3μ particle sizes (Fig. 12). Particles 5μ, and smaller, account for over 95 percent of the dust measured. The relative humidity also changed during the course of the study, increasing to 85 percent from values below 50 percent.

Comparison of dust concentrations for different forms of feed

Dust concentrations in chamber #1 were investigated for ground, pelleted, and ground and wetted feed fed twice a day with ventilation and air circulation. The dust measurements were taken prior to feeding. Feeding wetted and pelleted feed reduced the dust concentration in the chamber considerably (Fig. 13). The difference in dust concentration was significant ($p \leq 0.05$) for pelleted feed over the wetted feed (Table 2). The dust level for dry ground feed was about 2600 particles per 0.01 ft^3 for all particles greater than 0.5μ. This was 2.5 to 3 times the dust concentration measured from wetted or pelleted feed. The only difference in composition of the pelleted feed, compared to the ground feed, was a bonding agent. The spillage from the wetted feed kept the concrete floor damp.

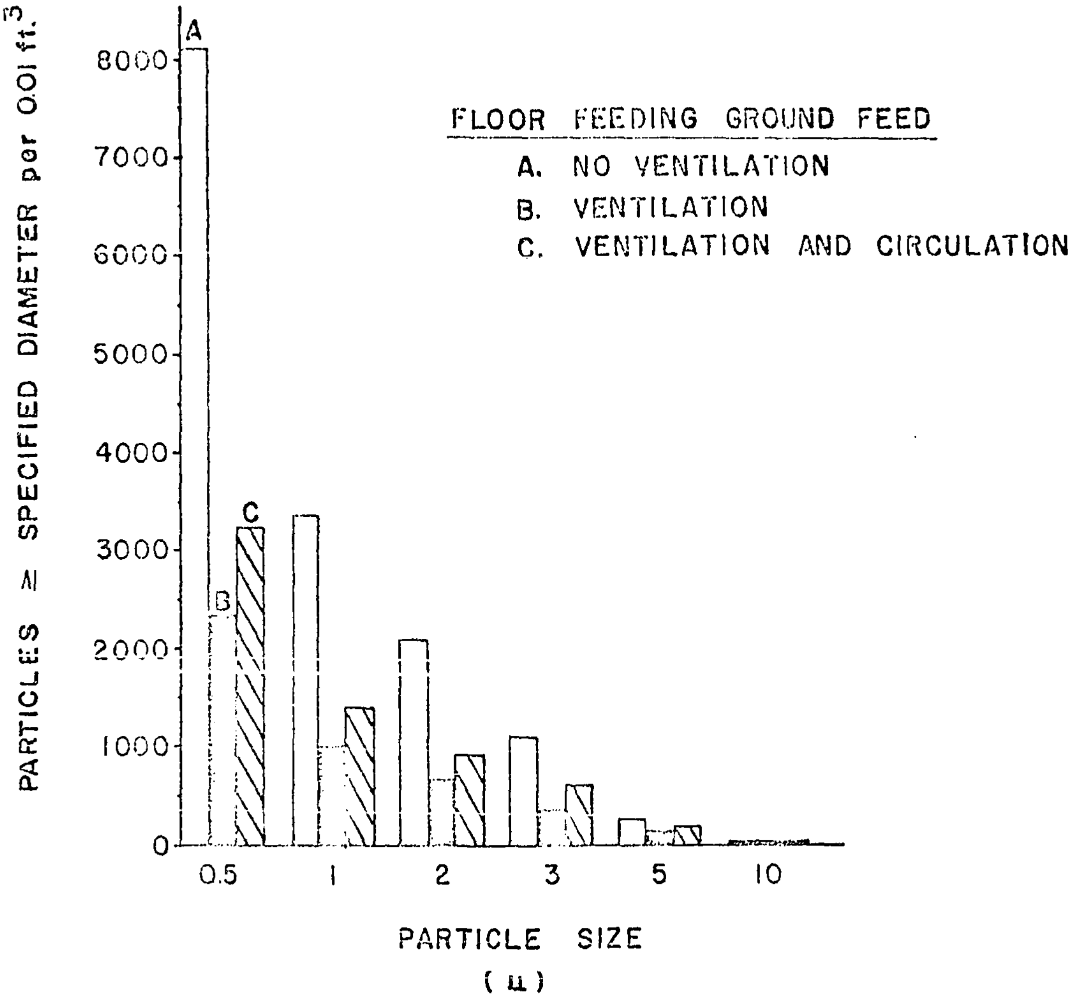


Figure 12. Dust levels for floor-feeding with different ventilation rates in chamber #1

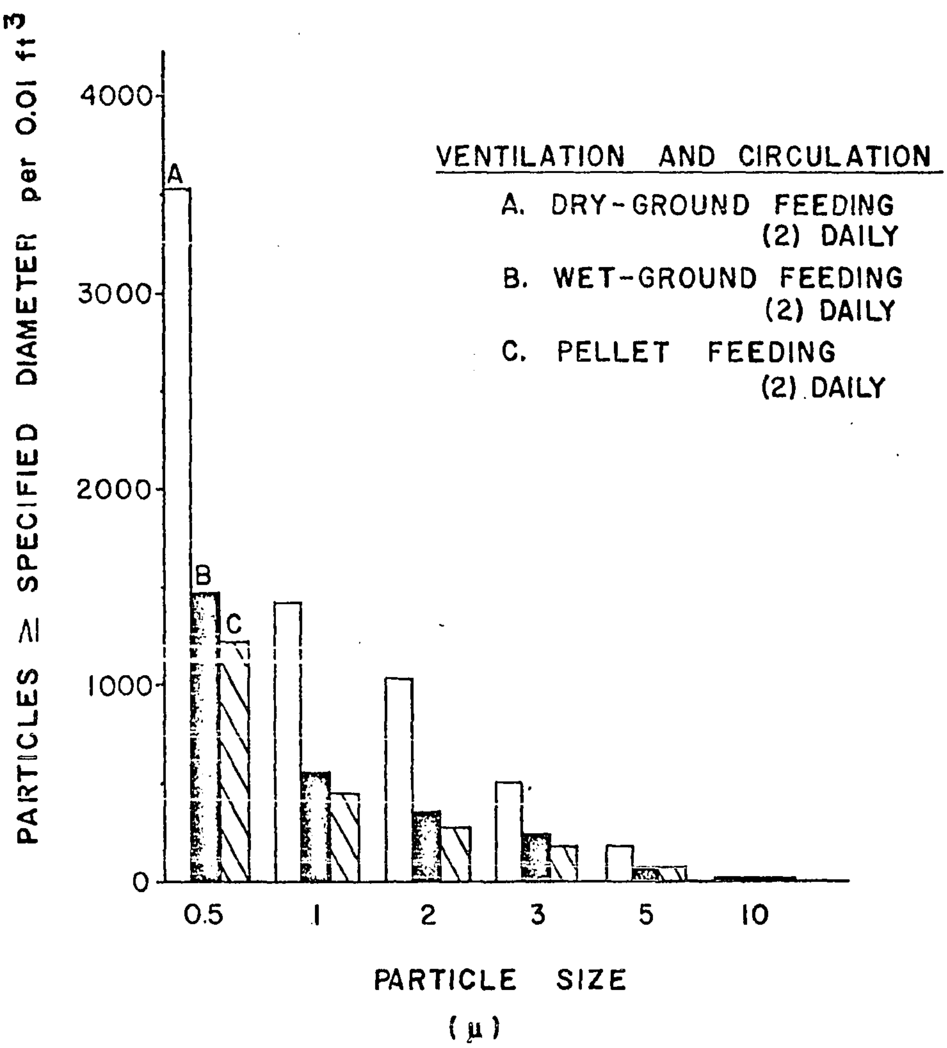


Figure 13. The comparison of dust levels on concrete for different forms of feed in chamber #1

Table 2. The effect of different forms of feeding

Treatment[a]	Particle size (μ)	Mean	Variance	t-test: Treatments compared	t-test: Value
A	0.5	3522	7,534,037	A-B	3.50**
B	0.5	1489	224,298	B-C	2.02*
C	0.5	1138	245,813	C-A	4.04**
A	2.0	993	511,155	A-B	3.90**
B	2.0	390	41,039	B-C	NS[b]
C	2.0	295	9,271	C-A	4.60**
A	5.0	124	14,810	A-B	3.13**
B	5.0	42	890	B-C	3.18**
C	5.0	17	84	C-A	4.19**

[a]Treatment A, B, and C refers to dry ground feed, wetted feed, and pelleted feed fed twice daily.

[b]NS = not significant.

*Denotes significance ($p \leq 0.05$).

**Denotes significance ($p \leq 0.025$).

<u>Dust concentrations for self-feeders with different ventilation rates</u>

The dust concentration in chamber #2 was measured under the same ventilation rates as chamber #1. The significance of ventilation is again shown in Table 3 with about a 50% reduction of dust particles greater than 0.5μ attributable to the ventilation fans. The circulation fans contribute to reducing the dust level by another 15 to 20% for the same particle sizes. Figure 14 shows reductions in dust concentration for particles greater than 1μ, 2μ, 3μ, and 5μ. About one-half the

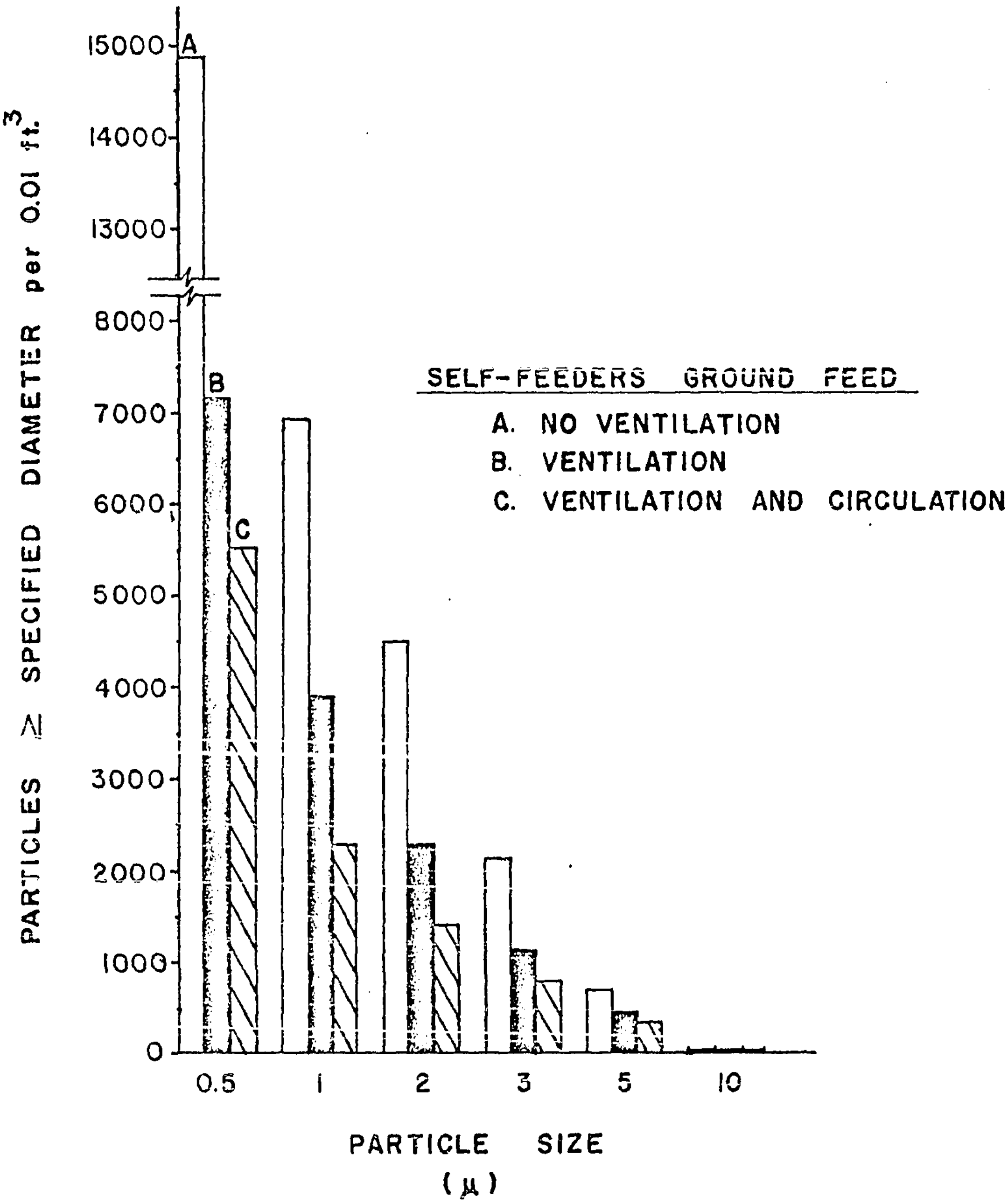


Figure 14. Dust levels for self-feeders with different ventilation rates in chamber #2

Table 3. The effect of different ventilation rates on self-feeding

Treatment[a]	Particle size (μ)	Mean	Variance	t-test Treatments compared	t-test Value
A	0.5	14906	50,667,158	A-B	2.86**
B	0.5	7150	18,281,400	B-C	NS[b]
C	0.5	5456	22,527,952	C-A	3.37**
A	2.0	4571	6,250,498	A-B	2.38**
B	2.0	2253	3,035,853	B-C	NS
C	2.0	1355	748,742	C-A	3.53**
A	5.0	407	66,076	A-B	NS
B	5.0	308	46,161	B-C	1.94*
C	5.0	188	19,088	C-A	2.24**

[a]Treatments A, B, and C refers to 0 cfm, 900 cfm, and 900 cfm ventilation with 3100 cfm air circulation, respectively.

[b]NS = not significant.

*Denotes significance ($p \leq 0.05$).

**Denotes significance ($p \leq 0.025$).

particles in suspension are between 0.5μ and 1μ, and less than 3 percent are 5μ or larger. The reason for the additional reduction in dust produced by the circulation fans in chamber #2, but not in chamber #1, is unknown.

Comparison of dust concentrations for different forms and frequencies of feeding

Dust levels in chamber #2 are shown in Figure 15 for ground, pelleted, wetted ground feed with ventilation and circulation fans on. Four feeding trials were made. The

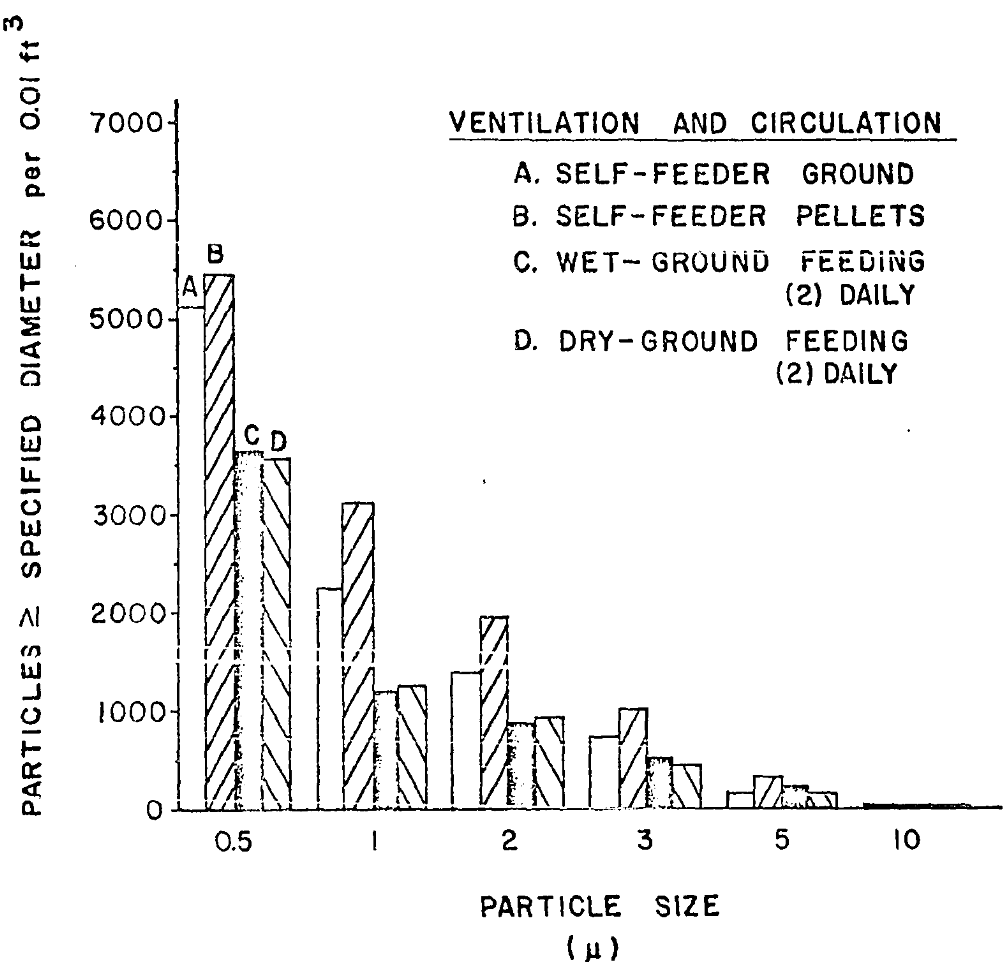


Figure 15. The comparison of dust levels on stainless-steel slatted floors for different forms and methods of feeding in chamber #2

trials were: A) ground feed in self-feeders, B) pelleted feed in self-feeders, C) ground feed fed twice daily, and D) wetted ground feed fed twice daily. In each case, the dust measurements were taken prior to feeding. There was no significant difference found (Table 4) between trials A and B, which used self-feeders; nor between trials C and D, which used twice a day feeding. There was, however, a 40 percent reduction in dust level in trials C and D, compared to trials A and B, for particles greater than 0.5μ, 1μ, 2μ, and 3μ. The activity of the animals was, on the whole, considerably less when fed only two times a day. The animals ground the pellets to a fine powder in the bottom of the self-feeder, causing the dust level to be about the same for ground and pelleted feed.

Dust decay rates for floor feeding

Three studies, two with and one without ventilation, were conducted with floor feeding in chamber #1, using a ground-feed and pelleted-feed ration. Without ventilation, it took approximately 40 minutes for the dust level shown in Figure 16 to decay to the level that existed prior to feeding. The dust concentration of 0.5μ, and larger, reached its minimum value about 1.5 hours after feeding. This was a 30 percent decrease in the value that existed prior to feeding. Shortly after reaching a minimum, the dust level started increasing, due to an increase in animal activity.

Table 4. The effects of different forms and methods of feeding on dust concentration

Treatment[a]	Particle size (μ)	Mean	Variance	t-test Treatments compared	t-test Value
A	0.5	5456	22,527,952	A-B	NS[b]
B	0.5	5432	5,154,968	A-C	2.66**
C	0.5	2617	1,446,027	A-D	2.47**
D	0.5	2776	2,134,628	B-C	3.68**
				B-D	3.38**
				C-D	NS
A	2.0	1354	748,742	A-B	NS
B	2.0	1989	1,273,645	A-C	2.13**
C	2.0	911	155,893	A-D	1.83*
D	2.0	930	380,962	B-C	2.94**
				B-D	2.77**
				C-D	NS
A	5.0	188	19,088	A-B	NS
B	5.0	194	6,205	A-C	3.10**
C	5.0	90	1,911	A-D	2.30**
D	5.0	108	6,266	B-C	3.89**
				B-D	2.83**
				C-D	NS

[a]Treatments A, B, C, and D refers to ground feed in self-feeders, pelleted feed in self-feeders, ground feed fed twice daily, and wetted ground feed fed twice daily.

[b]NS = not significant.

*Denotes significance ($p \leq 0.05$).

**Denotes significance ($p \leq 0.025$).

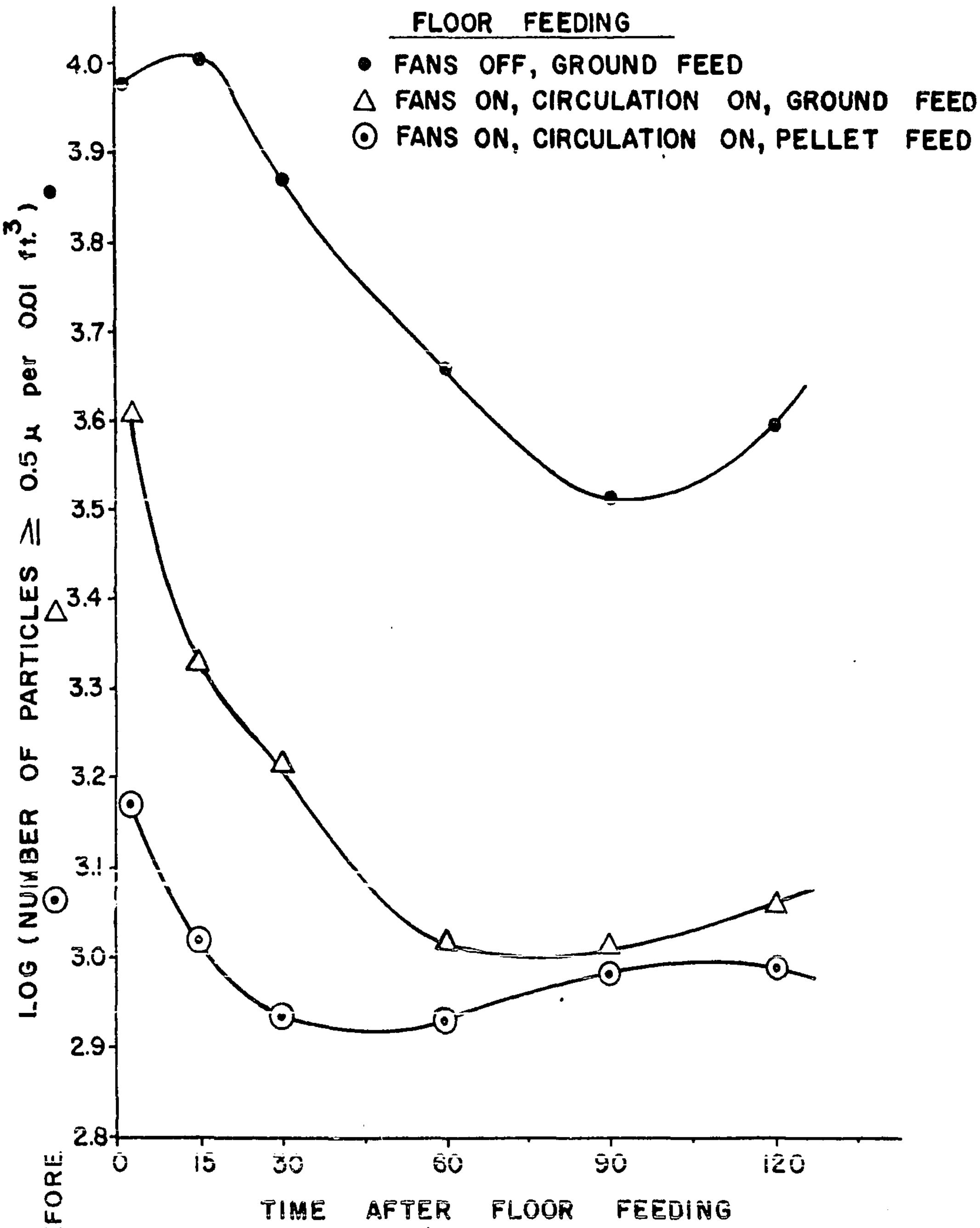


Figure 16. A comparison of the dust decay rates for different ventilation rates and forms of feed

The dust concentration for ground feed fed on the floor with a ventilation rate of 900 cfm and a circulation rate of 3100 cfm dropped within 10 minutes to the level that existed before feeding. Therefore, the dust concentration continued to decrease for about 1 hour reaching a final minimum of approximately 60 percent of the level that existed just prior to feeding.

Dust concentration for floor feeding of pellets, with the ventilation and circulation fans on, reached a minimum in about 45 minutes, giving a comparable decay rate to that for ground feed.

The curves were plotted for time starting directly after feeding to 2 hours of feeding. The slope of these lines are different with treatment A having the greatest slope (Table 5). As the dust concentration inside approaches the dust concentration outside, the slope approaches zero.

Decay rates with ionization

With no ventilation   Figure 17 shows a comparison of dust-decay for particles 0.5 μ and larger for the three different removal methods: (A) settling only, (B) air ionization by a negative corona discharge, and (C) air ionization by a negative corona discharge with a positive collector plate. Although the dust concentration was not the same for each set

Table 5. The effect of different ventilation rates and types of feed on dust decay rates

Time	Treatment A[a] Mean log	Treatment A[a] Variance	Treatment B[a] Mean log	Treatment B[a] Variance	Treatment C[a] Mean log	Treatment C[a] Variance
15	4.002	0.0356	3.321	0.0721	3.024	0.0267
30	3.877	0.0373	3.214	0.0541	2.938	0.0112
60	3.659	0.0406	3.067	0.0563	2.937	0.0512
90	3.519	0.0583	3.055	0.0687	2.982	0.0626

Treatment	Intercept	Slope	STD error time (B)	t-test Curves compared	t-test Value
A	4.079	-0.00646	0.000545	A-B	2.59*
B	3.338	-0.00356	0.000975	A-C	6.09**
C	2.987	-0.000337	0.000845	B-C	2.49*

[a]Treatment A, B, and C refers to fans off with ground feed, fans on, air on with ground feed, and fans on, circulation on with pellet feed, respectively.

*Denotes significance ($p \leq 0.05$).

**Denotes significance ($p \leq 0.025$).

of data, the efficiency of removal can be compared by the slope of the curves (Table 6). Both trials with ionization were considerably better than the trials without ionization. After 1.5 hr, two-thirds to three-quarters more dust was removed with the ionization and the collector plate charged than with no ionization. Ionization with the collector plate charged showed no improvement in decay rate than without the plate charged. After 1.5 hours, the dust concentration

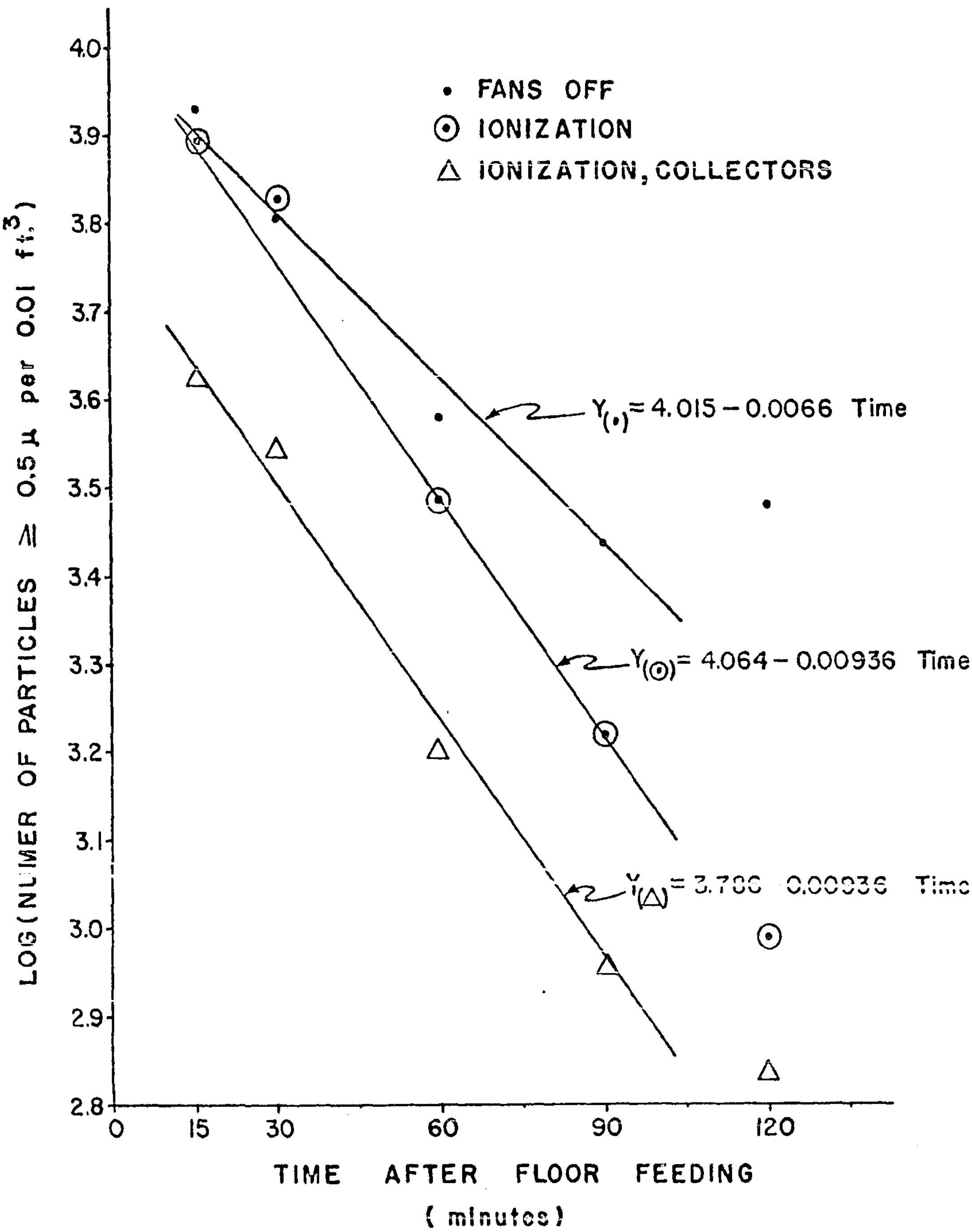


Figure 17. A comparison by least square curves of the decay rates with ionization with fans off in chamber #1

Table 6. The effect of ionization without ventilation on dust decay

Time	Treatment A[a] Mean log	Treatment A[a] Variance	Treatment B[a] Mean log	Treatment B[a] Variance	Treatment C[a] Mean log	Treatment C[a] Variance
15	3.393	0.041	3.626	0.027	3.895	0.007
30	3.805	0.039	3.541	0.027	3.827	0.014
60	3.580	0.049	3.198	0.028	3.484	0.050
90	3.443	0.067	2.951	0.062	3.224	0.068

Treatment	Intercept	Slope	STD error time (B)	t-test Curves compared	t-test Value
A	4.0147	-0.0066	0.000637	A-B	4.24**
B	3.7858	-0.0094	0.000602	B-C	NS[b]
C	4.0638	-0.0094	0.000681	C-A	3.19**

[a]Treatments A, B, and C refers to settling only, ionization, ionization with collector plate.

[b]NS = not significant.

**Denotes significance ($p \leq 0.025$).

started increasing.

With ventilation Figure 18 shows a comparison of dust decay rates with ventilation. The same three removal methods were compared as before (treatments A, B, and C, respectively), but with a ventilation rate of 900 cfm. Table 7 shows that ionization significantly improved the decay rate ($p \leq 0.05$); however, no improvement was found with the collector plate. After 1.5 hours, the dust concentration started

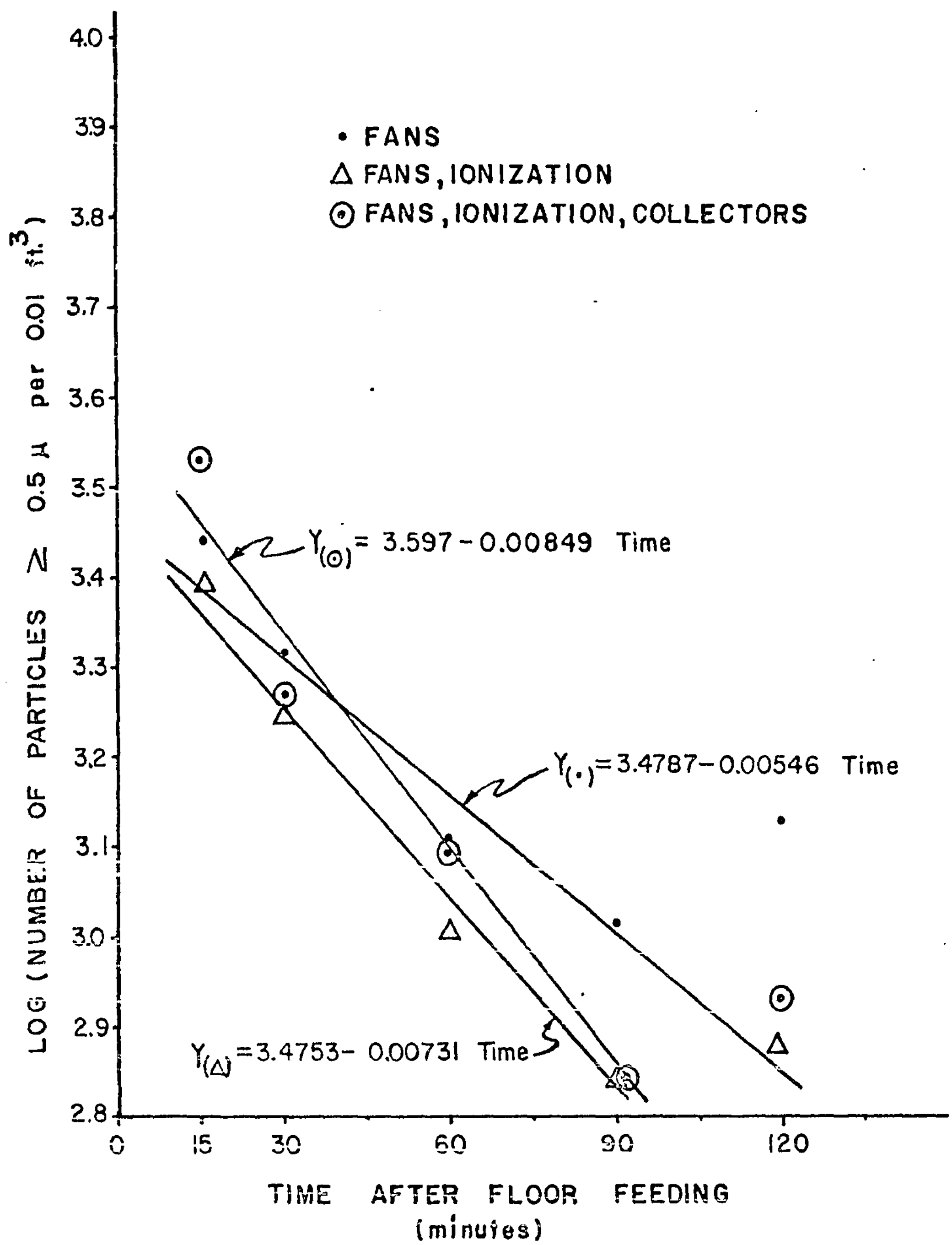


Figure 18. A comparison by least square curves of the decay rates with ionization with fans on in chamber #1

Table 7. The effect of ionization with ventilation on dust decay

Time	Treatment A[a]		Treatment B[a]		Treatment C[a]	
	Mean log	Variance	Mean log	Variance	Mean log	Variance
15	3.414	0.075	3.391	0.013	3.531	0.017
30	3.314	0.063	3.242	0.004	3.261	0.042
60	3.112	0.020	3.000	0.011	3.098	0.050
90	3.011	0.031	2.842	0.028	2.843	0.037

Treatment	Intercept	Slope	STD error time (B)	t-test	
				Curves compared	Value
A	3.4787	-0.00546	0.000602	A-B	2.09*
B	3.4753	-0.00731	0.000650	B-C	NS[b]
C	3.5972	-0.00849	0.001263	C-A	2.16*

[a]Treatments A, B, and C refers to fan at 900 cfm, 900 cfm with ionization, and 900 cfm with ionization and collector plate.

[b]NS = not significant.

*Denotes significance ($p \leq 0.05$).

increasing with the greatest total increase for fans on without ionization.

Particle-size distribution A comparison of particle-size distribution, for particles greater than or equal to the specified particle size, for each of the six removal methods, reported is shown in Figure 19, expressed as the average value for the six removal methods, with the high and low designated

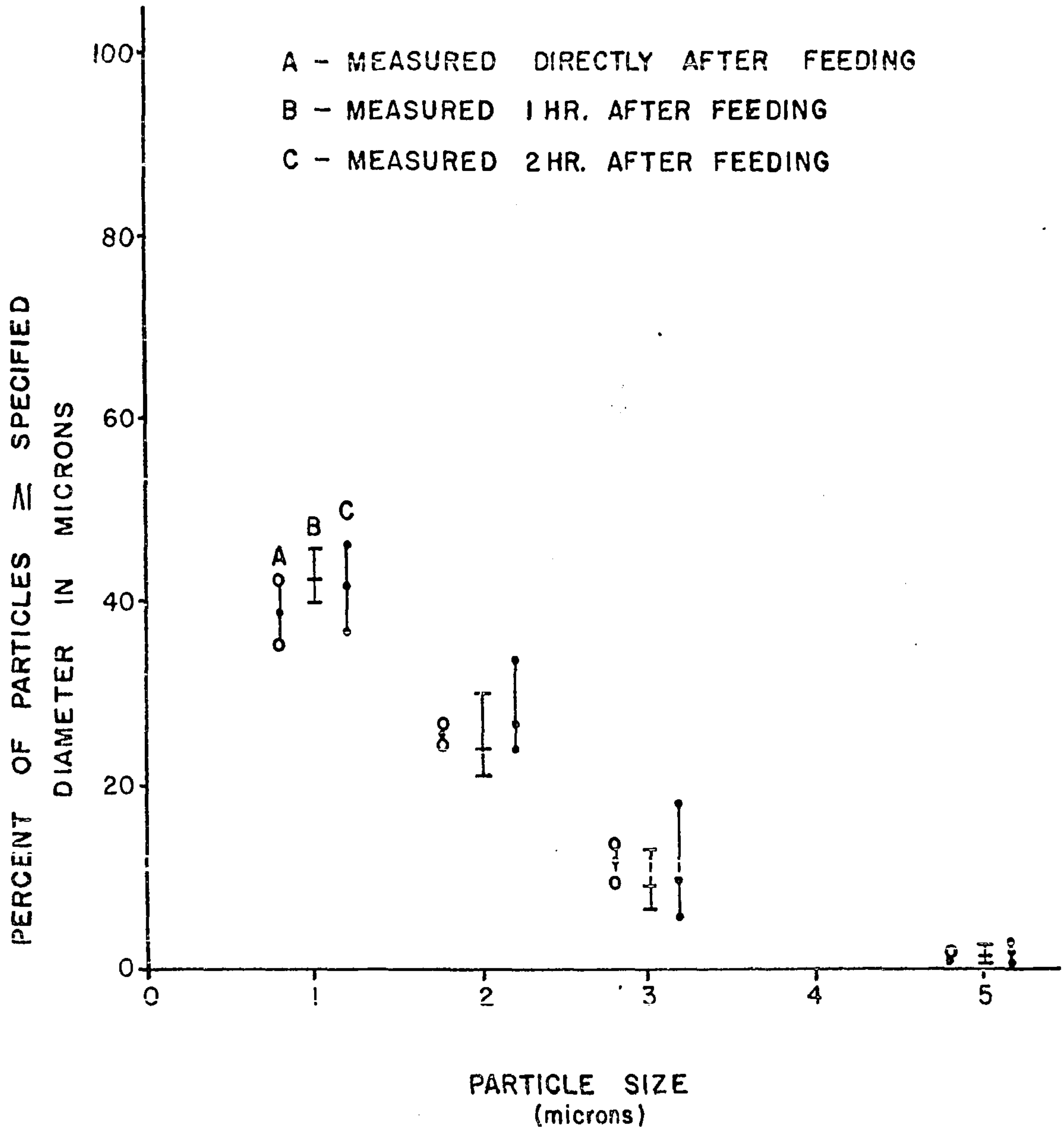


Figure 19. A comparison of particle-size distribution for particles greater than or equal to the specified particle size for each of the six removal methods directly after feeding, 1 hr after feeding, and 2 hr after feeding for chamber #1

at the end of each line. Each group of three lines represents the distribution for immediately after feeding, 1 hr after feeding, and 2 hr after feeding. No one method could be considered best for removing a particular particle size.

Collector plate The charged collector plate was effective in directing particles. Approximately 0.25 inches of dust accumulated on the vertically charged plate within a 3-week period. The collector plate was cleaned by spraying water on it after discharge. No scrubbing was required. The charged dust particles also collected on the uncharged chamber walls, but to a much lesser degree.

ENVIRONMENTAL CONTROL CHAMBER

A modified plant growth chamber located in the basement of one of the University Research Greenhouses was used to measure the effect of humidity on dust decay rates with varying circulation rates and ionization. Animals were not used in this study; thus eliminating any variation in dust readings due to animal activity. The chamber was modified as required to provide the desired environmental control, the addition of feed, and a sampling port.

Chamber

The chamber (Fig. 20) was a wood-frame structure, 5 ft long, 5 ft wide and 6.75 ft high, with an interior surface of painted plywood. The door was replaced with a smaller door containing a small removable window for dropping feed to the floor and a 0.5 in. sample port.

A heater, vaporizer and temperature and humidity controls (Fig. 21) were installed in the chamber to provide specific temperature-humidity settings. Control was maintained within $\pm$ 2°F and $\pm$ 4 percent relative humidity. The wiring diagram for the controls is in Appendix B.

Air circulation

Three fans were used for air circulation; a 10 in. fan to move air across the heating and cooling coils to provide temperature-humidity control, and two small centrifugal fans

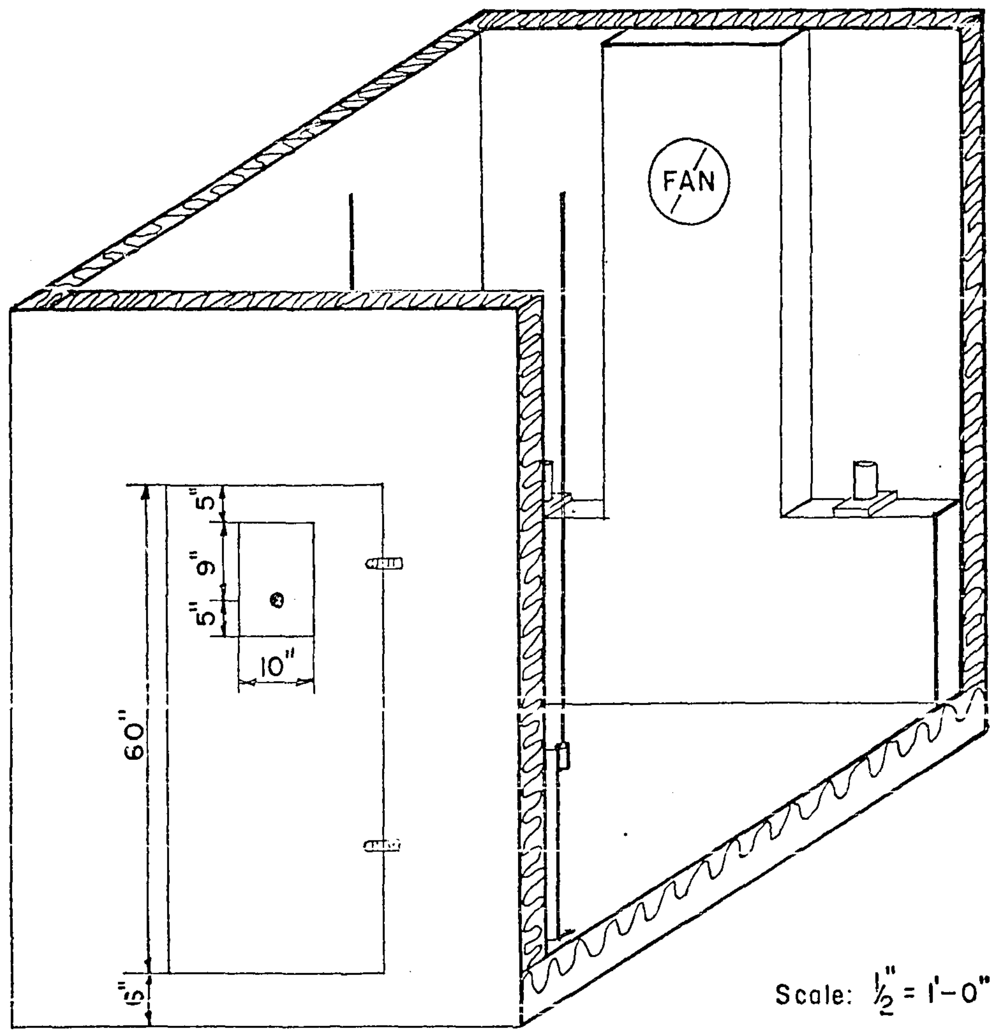
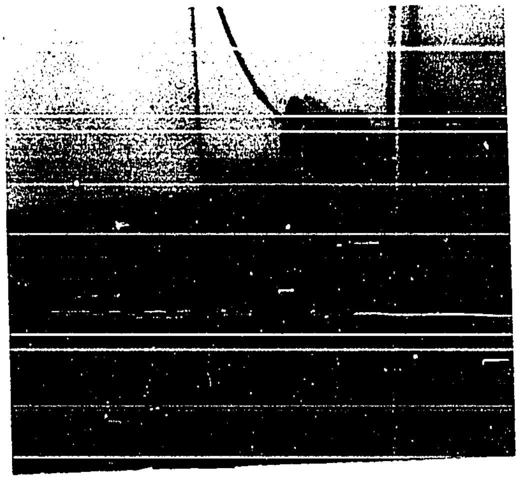
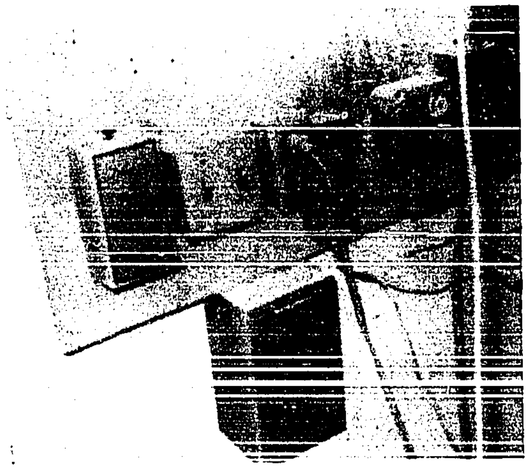
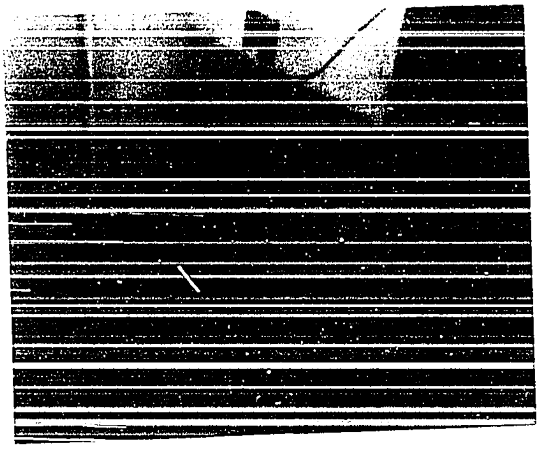


Figure 20. An isometric drawing of the Environmental Control Chamber

Figure 21. Equipment inside the chamber showing mixing fans, temperature-humidity controls, and collector plate





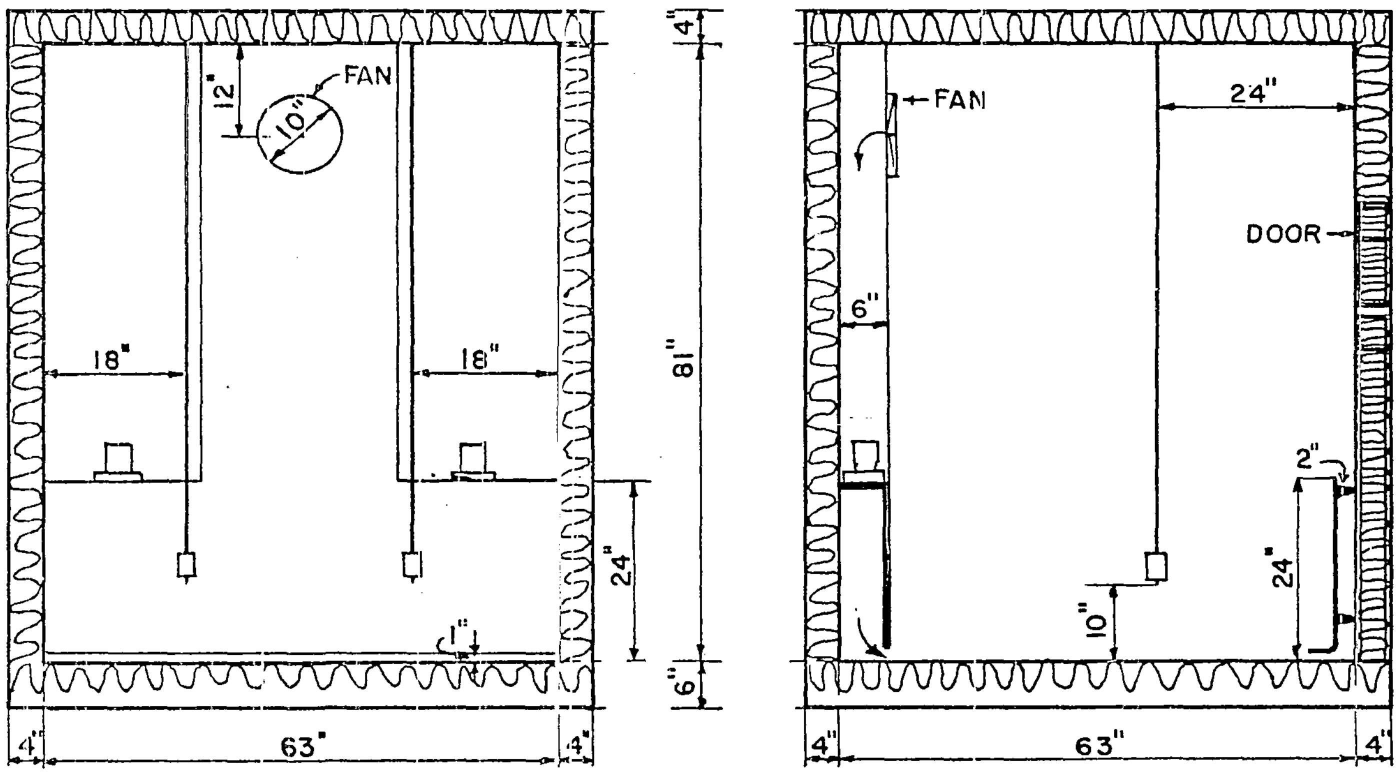


to mix the air in the room during the studies. A 2 in. slot at the bottom of the 5 ft wide plywood air supply duct (Fig. 22) provided the desired air flow pattern. Two variable transformers controlled the fan speeds; one for the 10 in. fan and the other one for the two mixing fans. Air movement from the two small mixing fans (Appendix B) was 76 cfm and 178 cfm for 60 and 100 percent voltage settings, respectively.

Air flow patterns for the two small fans (Fig. 23) were determined by smoke patterns; a quiescent condition observed in the upper one-third of the chamber at the lower voltage setting whereas at the higher setting almost complete mixing occurred.

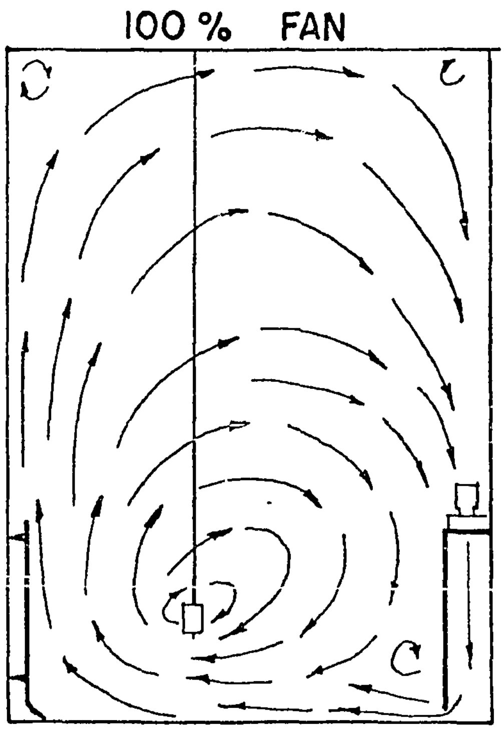
Feed dust

To produce a dusty atmosphere in the environmental chamber, ground feed (a 14 percent protein, corn-bean meal ration for finishing pigs) was dumped onto the floor from a one gallon container at a distance of 3.5 ft above the floor. Feed was stored overnight inside the chamber in a 15 in. diameter by 28 in. high barrel (Fig. 24). So that the feed dust would be in moisture equilibrium with the chamber air, a 1/50 hp centrifugal fan was used to force air, 58 cfm, through the feed and out through a filter in the bottom of the barrel. During the tests, the feed was removed to the outside of the chamber.



Scale: ½" = 1'-0"

Figure 22. Cross-sections of the environmental chamber with ionization equipment



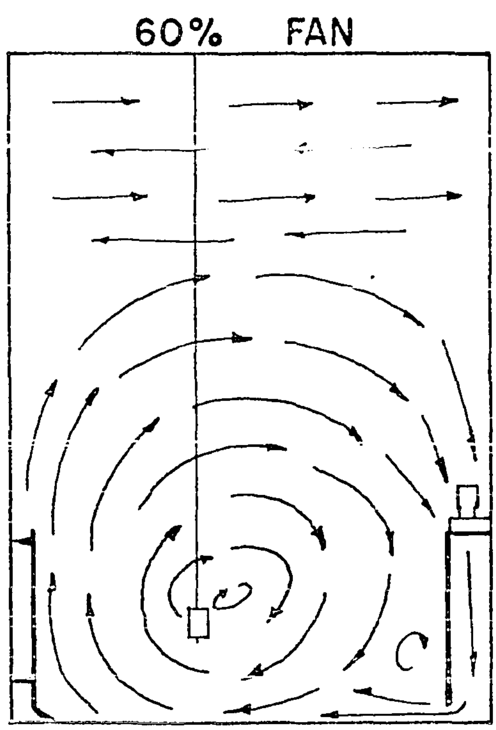
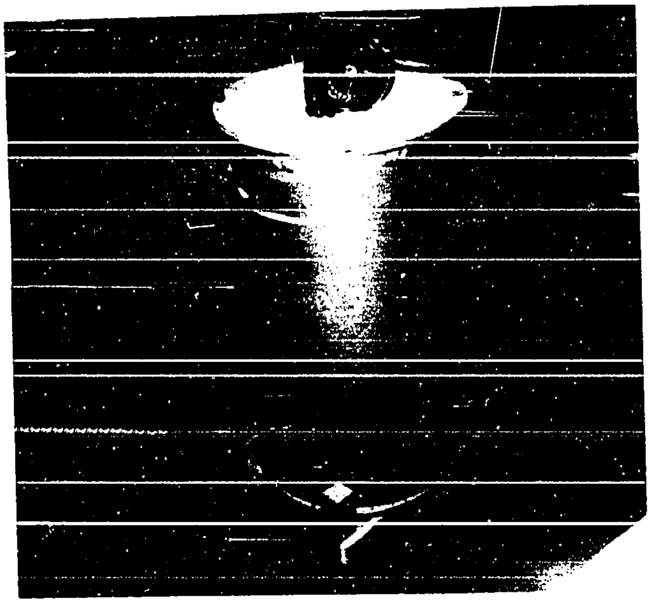
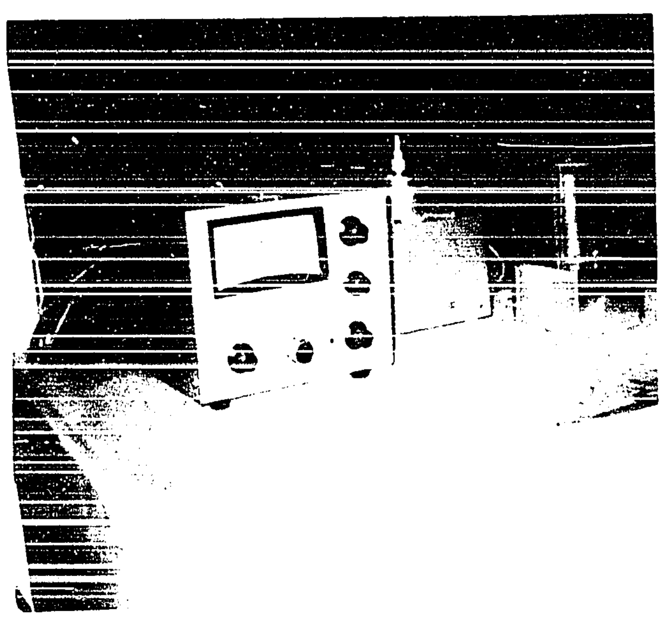


Figure 23. Air flow patterns in the test chamber for circulating fans operating at 60% and 100% voltage settings

Figure 24. Feed storage container with blower to bring feed in equilibrium with chamber air

Figure 25. A picture of the Keithly, model 640, electrometer with a coaxial probe attached





Ionization equipment

The ionization equipment used in the environment chamber was the same as that earlier described in the animal experiment Section. The two discharge electrodes were located (Fig. 22) 10 in. above the floor, 24 in. from the door, and 18 in. from each of the sidewalls.

An aluminum collector plate, 30 in. by 56 in., was located in front of the door and directly opposite to the air duct so as to have an air flow across it. The voltages on the discharge and collector electrodes were 12kV negative with respect to ground and 8kV positive with respect to ground, respectively.

Ion measurement Equipment was not available at the time of these tests for counting the air ions produced per unit volume of air in the chamber; however, measurements were made with a coaxial cylinder probe (Fig. 25) which gave the intensity of electron flow from the corona region. The probe consisted of an outer cylinder of screen wire, 4.25 in. high by 2 in. diameter and an inner cylinder of steel pipe, 3.5 in. high by 0.62 in. diameter. Current measurements to the inner cylinder were made using a Keithly, model 640, electrometer. A 10^8 megohm input resistor gave a full-scale indication of 3.0×10^{-15} amperes at a range setting of 300 millivolts. The ionization level between two charging electrodes, 2 ft apart, was only slightly higher than that produced at 1 ft distance from a single source (Appendix K).

Data collecting

All readings were taken with the same sampling instrument at a height of 46 in. above the chamber floor and 6 in. from the inside wall surface. Each time a series of readings was completed, the fan was turned on to circulate air across the heating and cooling coils to lower the temperature and humidity below the desired value by 2°F and 3 percent, respectively. While taking the measurements, the coil fan was turned off to eliminate any further adjustment in temperature and humidity.

The circulating fans were turned on before each dump; then as soon as the dump was completed, all the controls were adjusted to the appropriate position for the test. Readings began within 15 seconds after the feed was dumped. Air was sampled for 1 minute, the number of particles greater than or equal to the specified particle diameter per 0.01 ft^3 counted and; then the diameter setting changed manually to the next size range and the procedure repeated.

RESULTS FROM ENVIRONMENTAL CHAMBER

The tests in the environmental chamber were conducted from April to November, 1973. Measurements were obtained on the effects of humidity, air circulation, ionization, and a charged collector plate on the dust concentration decay rate. Table 8 gives a summary of the least squares fits of the equation, log N = b_o - (b_1 x Time), for the means of the number of particles of 0.5μ or greater size and 2μ or greater size, for the times, T = 1, 4, 7, 10, etc. The correlation coefficient, r, was close to unity in each treatment indicating that the decay rates were closely approximated by the least square fit. To determine the difference between treatments, each run within a treatment was fitted to a least squares line. The time for equal intervals of decay was calculated for each run from the least squares curve; then a t-test was made to determine the level of significance between treatments.

Effect of humidity on dust decay rates

With varying ventilation The difference between the dust decay rates for treatments 1 and 2 was not significant as shown in Table 9. With the fans at the 60 percent voltage setting, the slopes of the two curves (Fig. 26) were almost the same and about 1.5 to 2 times greater than without ventilation. Treatments 5 and 6 were significantly different ($p \leq 0.01$).

Table 8. The effect of circulation fans, ionization, charged collector plates, and relative humidity on the decay rates of feed dust

Treatment	Fans[a]	Ions[b]	Col[c]	RH[d]	No. of runs	0.5μ b_o[e]	0.5μ b_1[f]	0.5μ Prob>F	0.5μ R-square	2μ b_o	2μ b_1	2μ Prob>F	2μ R-square
1	0	0	0	0	5	3.365	-0.0100	.0001	0.98	2.941	-0.0160	.0001	0.99
2	0	0	0	1	12	3.136	-0.0077	.0001	0.97	2.725	-0.0115	.0001	0.98
3	1	0	0	0	19	3.458	-0.0153	.0001	0.97	3.096	-0.0224	.0001	0.99
4	1	0	0	1	12	3.307	-0.0150	.0001	0.80	2.865	-0.0206	.0001	0.85
5	2	0	0	0	6	3.507	-0.0531	.0001	0.94	3.087	-0.0961	.0001	0.97
6	2	0	0	1	10	3.239	-0.0527	.0014	0.96	2.720	-0.0975	.0006	0.95
7	0	1	0	0	10	3.742	-0.0566	.0001	0.98	3.337	-0.0609	.0001	0.99
8	0	1	0	1	10	3.356	-0.0480	.0002	0.99	3.012	-0.0550	.0002	0.99
9	1	1	0	0	10	3.345	-0.0625	.0004	0.99	2.966	-0.0715	.0004	0.99
10	1	1	0	1	10	3.063	-0.0580	.0012	0.97	2.592	-0.0755	.0003	0.99
11	2	1	0	0	9	3.491	-0.1093	.0009	0.98	3.067	-0.1671	.0003	0.99
12	2	1	0	1	10	3.156	-0.1039	.0039	0.95	2.650	-0.1471	.0022	0.97
13	2	1	1	0	7	3.435	-0.0711	.0005	0.99	3.006	-0.0700	.0014	0.96
14	0	1	1	0	12	3.780	-0.0900	.0050	0.90	3.211	-0.0753	.0089	0.86

[a]Fans = 0, 1, 2; denotes fans off, fans at 60%, and fans at 100% voltage setting, respectively.

[b]Ions = 0, 1; denotes ionization off, ionization on, respectively.

[c]Col = 0, 1; denotes collector plates not charged, collector plates charged, respectively.

[d]RH = 0, 1; denotes relative humidity at 50% and 85%, respectively.

[e]b_o is the intercept of the least square curve, log N - b_o - (b_1 x Time).

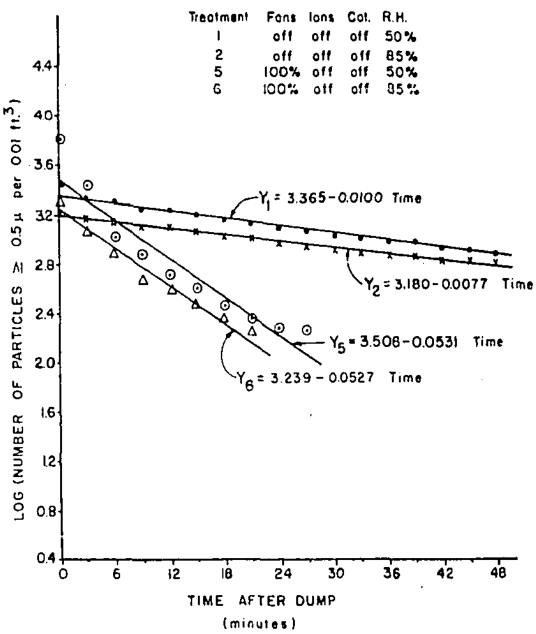
[f]b_1 is the slope of the least square curve, log N = b_o - (b_1 x Time).

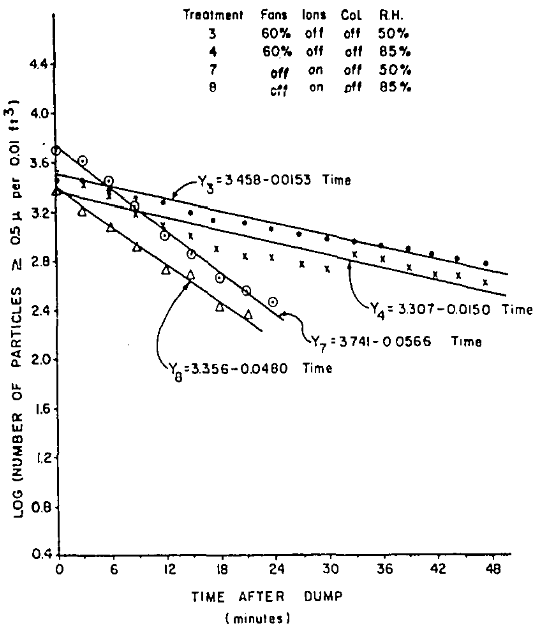
Figure 26. Least square curves for dust decay rates with fans off and fans at 100 percent voltage for 50 and 85 percent relative humidity

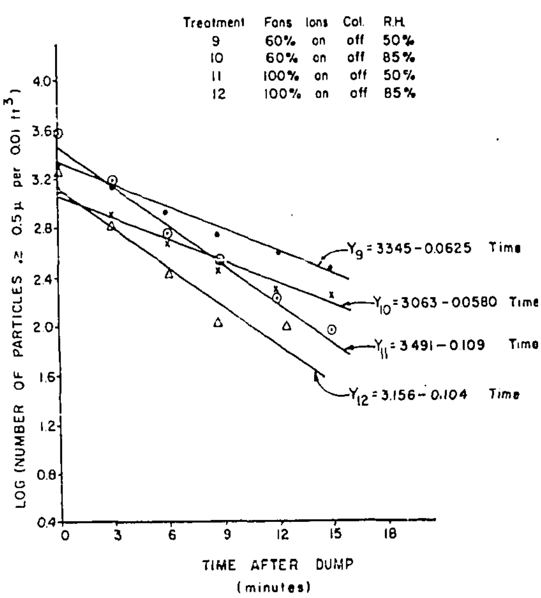
Figure 27. Least square curves for dust decay rates with fans at 60 percent voltage, and fans off with ionization for 50 and 85 percent relative humidity

Figure 28. Least square curves for dust decay rates with fans at 60 percent voltage with ionization and fans at 100 percent voltage with ionization for 50 and 85 percent relative humidity

Figure 29. Least square curves for dust decay rates with fans off, fans at 60 percent voltage, and fans at 100 percent voltage for 85 percent humidity


Treatment Fans Ions Col. R.H.
1 off off off 50%
2 off off off 85%
5 100% off off 50%
6 100% off off 85%
Y1 = 3.365-0.0100 Time
Y2 = 3.180-0.0077 Time
Y5 = 3.508-0.0531 Time
Y6 = 3.239 - 0.0527 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft.3)
TIME AFTER DUMP
(minutes)


Treatment Fans Ions Col R.H.
3 60% off off 50%
4 60% off off 85%
7 off on off 50%
8 off on off 85%
Y3 = 3.458-0.0153 Time
Y4 = 3.307-0.0150 Time
Y7 = 3.741-0.0566 Time
Y8 = 3.356-0.0480 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft.3)
TIME AFTER DUMP
(minutes)


Treatment Fans Ions Col. R.H.
9 60% on off 50%
10 60% on off 85%
11 100% on off 50%
12 100% on off 85%
Y9 = 3.345-0.0625 Time
Y10 = 3.063-0.0580 Time
Y11 = 3.491-0.109 Time
Y12 = 3.156-0.104 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft.3)
TIME AFTER DUMP
(minutes)

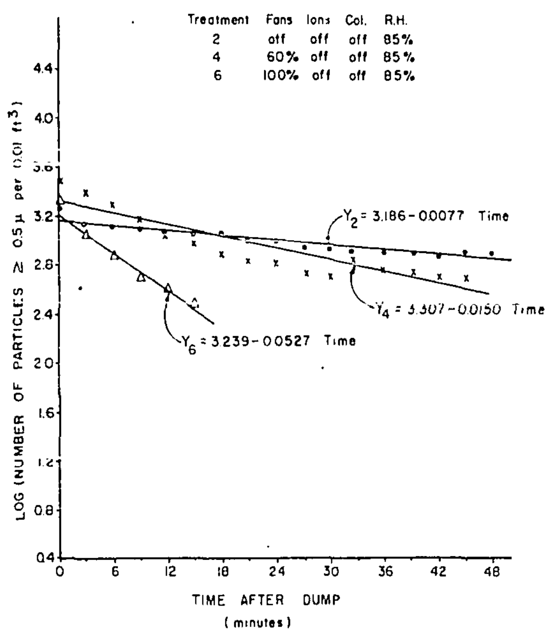

Treatment Fans Ions Col. R.H.
2 off off off 85%
4 60% off off 85%
6 100% off off 85%
Y2 = 3.186-0.0077 Time
Y4 = 3.307-0.0150 Time
Y6 = 3.239-0.0527 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft.3)
TIME AFTER DUMP
(minutes)

Table 9. The effect of humidity on dust decay rates for all particles $\geq 0.5\mu$

Treatment[a]	T[b]	S[c]	t-test Curves compared	Values
1	47.00	5.48	1-2	NS[d]
2	65.20	19.10		
3	29.83	21.77	3-4	NS
4	19.00	5.30		
5	7.04	0.78	5-6	11.50**
6	10.30	0.05		
7	8.31	2.31	7-8	2.2*
8	10.53	2.24		
9	7.39	0.96	9-10	NS
10	7.17	0.44		
11	3.58	0.15	11-12	NS
12	3.76	0.48		

[a]Treatments are defined in Table 8.

[b]Denotes the mean for the time required for dust to decay from 1500 particles to 500 particles.

[c]Denotes standard deviation of the time values.

[d]NS = not significant.

*Denotes significance ($p \leq 0.025$).

**Denotes significance ($p \leq 0.01$).

<u>Ionization at different ventilation rates</u> Treatments 7 and 8 (without air circulation) were significant ($p \leq 0.025$), but decay rates were not significantly different for the treatments where circulation fans operated at 60 and 100 percent voltage settings. In each set of comparisons, the differences in slopes (Figs. 27 and 28) were less than 10 percent of the larger value as measured on a semi-log scale.

<u>Effect of air circulation on dust decay rates</u>

The effect of air circulation on dust decay rates were compared for circulation fans off and for fans at 60 percent and 100 percent voltage settings. Both sets of curves (Fig. 29) were significant ($p \leq 0.01$) as shown in Table 10. The slopes of the curves for treatment 4 and 6 were approximately 2 times and 7 times the slope of treatment 2, respectively (Table 8). The chamber walls acted as an impingement surface for the particles; thus the greater the air circulation rate, the greater the force needed to remove the particles from the air stream. Figure 14 shows the air flow patterns for fans at 60 and 100 percent voltage setting. A combination of inertial and gravitational forces caused the 2μ and larger particles to result in a 1.5-1.6 times greater slope with no ventilation, and 1.8-1.9 times greater slope with fans at 100 percent voltage setting, than the slope for 0.5μ and larger particles under the equivalent conditions.

Table 10. The effect of air circulation on dust decay rates for all particles $\geq 0.5\mu$ at 85 percent relative humidity

Treatment[a]	T[b]	S[c]	t-test Curves compared	t-test Values
2	65.20	19.10	2-4	6.71**
4	19.00	5.30	4-6	4.64**
6	10.30	0.06		

[a]Treatments are defined in Table 8.

[b]Denotes the mean for the time required for dust to decay from 1500 particles to 500 particles.

[c]Denotes standard deviation of the time values.

**Denotes significance ($p \leq 0.01$).

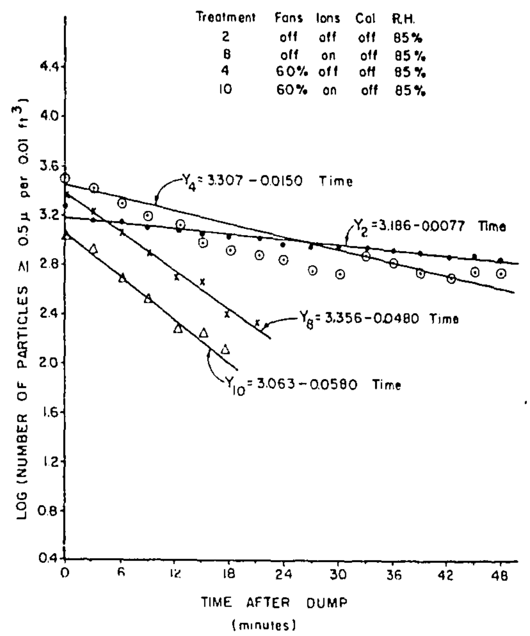
Effect of air ionization on dust decay rates

Under quiescent conditions, ionization greatly increased the decay rates (Fig. 30). The slope of the curve was about 6 times greater with ionization than by gravity only. With fans operating at the 60 percent voltage setting, the decay rate was also greater as indicated by a 2 to 3 times greater slope. Similar increases in decay rate were produced with the fans operating at the 100 percent voltage setting (Fig. 31). In each comparison (Table 11), the difference between treatments was significant ($p \leq 0.01$).

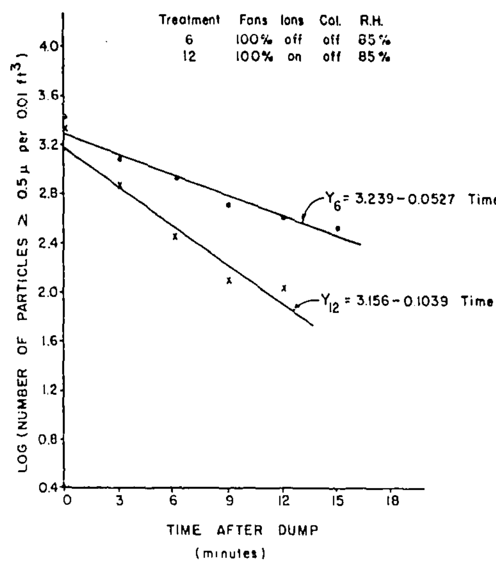
Figure 30. Least square curves for dust decay rates with fans off and fans at 60 percent voltage with and without ionization

Figure 31. Least square curves for dust decay rates with fans at 100 percent voltage with and without ionization

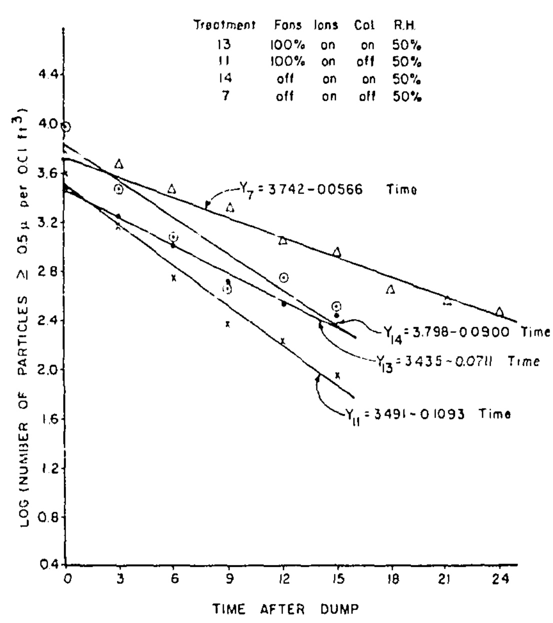
Figure 32. Least square curves for dust decay rates with fans off with ionization and fans at 100 percent voltage with ionization for collector plate grounded and charged to 8 kV



Treatment Fans Ions Col R.H.
2 off off off 85%
8 off on off 85%
4 60% off off 85%
10 60% on off 85%
Y_4 = 3307 - 00150 Time
Y_2 = 3.186 - 00077 Time
Y_8 = 3.356 - 0.0480 Time
Y_{10} = 3.063 - 0.0580 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft³)
TIME AFTER DUMP
(minutes)



Treatment Fans Ions Col. R.H.
6 100% off off 85%
12 100% on off 85%
Y_6 = 3.239 - 0.0527 Time
Y_{12} = 3.156 - 0.1039 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft³)
TIME AFTER DUMP
(minutes)



Treatment Fans Ions Col R.H.
13 100% on on 50%
11 100% on off 50%
14 off on on 50%
7 off on off 50%
Y_7 = 3742 - 00566 Time
Y_{14} = 3.798 - 0.0900 Time
Y_{13} = 3435 - 0.0711 Time
Y_{11} = 3491 - 0.1093 Time
LOG (NUMBER OF PARTICLES ≥ 0.5 μ per 0.01 ft³)
TIME AFTER DUMP
(minutes)

Table 11. The effect of air ionization on the dust decay rates for all particles $\geq 0.5\mu$

Treatment[a]	T[b]	S[c]	t-test Curves compared	Values
2	65.20	19.10	2-8	8.58**
8	10.53	2.24		
4	19.00	5.30	4-10	6.65**
10	7.17	0.44		
6	10.30	7.12	6-12	38.59**
12	3.76	0.47		
13	6.30	0.02	13-11	6.45**
11	3.58	0.15		
14	3.99	0.46	14-7	5.34**
7	8.31	2.29		

[a]Treatments are defined in Table 8.

[b]Denotes the mean for the time required for dust to decay from 1500 particles to 500 particles.

[c]Denotes the standard deviation of the time values.

**Denotes significance ($p \leq 0.01$).

Collector plate The collector plate increased dust removal in treatment 14 under quiescent conditions, but a reverse effect (treatment 13) resulted with air circulation. The slope of the curve (Fig. 32) increased by 1.6 times in treatment 14 in comparison to treatment 7 without ionization; and decreased by about the same amount in treatment 13 in comparison to treatment 11 without ionization. Both sets of treatments were significant ($p \leq 0.01$).

DISCUSSION

The major purpose of this study was to first examine how the dust concentration in confinement buildings varied with different environmental and management conditions; then to determine if air ionization could effectively remove the dust.

The studies in the animal chambers at AISI show that the infiltration rate of dust was very rapid; the dust concentration was approximately the same inside the building without animals as the outside dust concentration. The data also show that the base level can change by a magnitude of 80 to 90 percent and that it is not practical to try to control below this value by ventilation.

Frequency of feeding, method of feeding, and the form of feed affects the dust concentration in a building. In comparing various feeding methods on stainless steel slatted floors with ventilation and air circulation, the dust concentrations were approximately the same for ground feed and pelleted feed fed in self-feeders; however, the dust concentration was much less when the pigs were fed ground or wetted ground feed in troughs twice a day. The pelleted feed in the bottom of the self-feeders was ground up by the pigs' snouts to a fine powder similar to ground feed. Differences in the dust concentration with self-feeders and feeding twice daily resulted from a decrease in animal activity when fed only twice daily.

When feeding on concrete with ventilation and air circulation, differences in the dust concentration varied with forms of feeding. Dust concentration was less than half for pelleted feed fed on the floor and wet ground feed fed in troughs compared to floor feeding ground feed. The concrete floors were slightly wet when wet ground feed was fed in troughs.

Ventilation reduced the dust concentration by more than 50 percent compared to no ventilation for all dust particles 3μ and smaller. Ventilation was most effective in removing dust when the dust concentration in the building was much greater than the outside concentration.

Air ionization was an effective control method to reduce dust concentration. One and one-half hours after feeding without ventilation in the chamber, two-thirds to three-fourths more dust was removed with ionization and with ionization and collector plate than by settling. Ionization also increased the dust decay rate with ventilation, but not as much as without ventilation. Dust collected on the collector plate to approximately 0.25 in. which was easily removed by spraying water on the plate.

The tests in the environmental chamber gave both validity to the animal chamber studies and new insight on the effectiveness of ionization. For instance, comparisons in the AISI chambers ignored the effect of relative humidity. The environmental chamber studies showed this to be a valid omission.

The environmental chamber studies also showed that the ionization collector plate is substantially reduced in effectiveness if not located properly in relation to air currents; therefore, its location in an animal building could similarly be critical.

Wood is usually considered to be electrostatically neutral. However the dust particles were attracted to these surfaces in the environmental chamber. Although this could be considered desirable in terms of air cleaning, it is less desirable in terms of preventing building deterioration. Contamination of the atmosphere by small particles was encountered twice during testing in the environmental chamber. Both times the contamination occurred as the chamber was being changed from high relative humidity studies with ionization to low relative humidity studies. For instance, on August 1, 1973, runs were completed at 85 percent relative humidity, with ionization, and the controls were changed to 50 percent relative humidity in preparation for the August 2 runs. Table 12 shows the changed decay rate caused by the contaminated chamber.

To determine why only small particles (primarily < 1μ) were contaminating the air, two-hundred mesh carbon grids, were taped to the ceiling, to a sidewall (two feet from the floor) and to the collector plate. Under electron microscopic examination, these grids gave a measure of the particle size distribution for the particles attached to the surfaces (Table

Table 12. Runs on August 2, 1973 without fans and ionization off at 50°F, RH = 50%

Time	$\geq .5\mu$	$\geq 2\mu$	$\geq 5\mu$
10:17	9,580	4,070	670
10:20	7,350	3,070	523
10:23	5,850	2,570	377
10:26	5,340	2,160	295
10:29	6,350	1,990	267
10:32	12,370	1,760	98
10:35	32,230	1,230	77
10:38	69,600	1.070	80
10:41	108,500	860	76
10:44	161,700	877	57
10:47	217,600	765	59
10:50	253,700		

13). The results suggest the dust particles most likely dried out on the ceiling and fell back into the air. This phenomenon raises the question as to whether or not similar particulate contamination occurs in animal confinement buildings.

From the results of these studies, it now seems that air ionization is a promising dust control system for animal confinement buildings: (1) the system can handle the large dust loading rates, (2) the system will operate throughout the entire humidity range, (3) the system is inexpensive to install and operate, and (4) the system will remove submicron dust particles from the air. However, before these systems can gain their full potential, they must be optimized with respect to voltage, current, spacing of charging electrodes, location and spacing of collector plates, automatic collector plate washers, and air circulation patterns.

Table 13. Microscope study showing a summary of the particles counted on the carbon grids, with fans off, ionization and collector plate on, in the environmental chamber

Number of particles per sample area from two carbon grids											
Ceiling				Sidewall				Collector plate			
.5-1μ	1-3μ	3-5μ	5-10μ	.5-1μ	1-3μ	3-5μ	5-10μ	.5-1μ	1-3μ	3-5μ	5-10μ
14	1	0	0	16	4	1	0	90	20	1	
15	0	0	0	5	1	0	0	85	15	2	
16	1	0	0	12	2	0	0	50	19	1	
20	3	1	1	16	3	1	0	63	23	4	1
26	1	0	1	21	5	2	0	140	14	2	
28	1	0	0	9	2	0	1	148	46	3	1
6	0	0	0	5	0	0	0	90	26	4	2
8	0	0	0	8	1	0	0	50	14	1	0
93%[a]	5%	1%	1%	80%	15%	4%	1%	78%	19%	2%	1%

[a]% of total particles on specific surface.

SUMMARY

Knowledge of both the particle size and concentration is necessary to the design of a control system that is capable of efficiently removing particulates from an animal atmosphere. Tests were made to determine these quantities, and the results then used to evaluate the potential of controlling the dust concentration by ionization.

Animal experiment

Several different methods for reducing the dust concentration were tried in the AISI building. Included were variations in the method of feeding, the frequency of feeding, the form of feed, the ventilation rate, and the use of ionization. The more important findings in the study are:

1. The base dust concentration inside a confinement building can be predicted by measuring the outside dust concentration.
2. Animal activity and dust concentrations are higher when self-fed than when fed twice daily.
3. Dust concentration is 50 to 75 percent less when feeding twice daily than with self-feeders.
4. The dust concentration is lower for floor-feeding of pellets than for ground feed fed on a concrete floor.
5. There is no significant difference in dust concentrations for pellets and ground feed fed in self-feeders.

6. There is no significant difference in dust concentrations in feeding ground feed twice daily and wet feed twice daily in a trough on stainless steel slatted floors.

7. Air ventilation at 35 cfm per animal reduced the dust level to 50 percent of that with no ventilation.

8. The effectiveness of air ventilation in removing dust decreases as the dust concentration decreases.

9. Ninety-five percent of the dust in swine buildings is in particle sizes considered damaging to human lungs.

10. Fifty percent of the dust within the measured ranges was made up of particle sizes between 0.5μ and 1μ.

11. Ionization is relatively more effective under zero-ventilation than with ventilation.

12. Ionization also increases the dust decay rate when used with ventilation fans.

13. More dust is collected on ceiling, sidewalls, and exhaust-fan motors and controls when ionization is used.

14. Dust particles can be directed to a highly charged plate opposite in charge to the dust particles.

15. For ionization to be an effective method of controlling dust in an animal confinement building, the ceiling and sidewalls should be charged to direct particles to a specific surface that can be

periodically cleaned by flushing.

Environmental studies

The environmental chamber was used to obtain better control of air movement, temperature, and humidity than could be obtained in the animal chamber at AISI. The following findings were made:

1. After dust becomes airborne, the humidity has little effect on the decay rate.
2. Dust removal by air ionization is not effected by humidity.
3. Dust decay rates increase with an increase in air circulation.
4. The air movement pattern across a collector plate affects the collection efficiency of the ionization system.

SUGGESTIONS FOR FUTURE RESEARCH

The research described in this study represents a beginning. It is a start on finding some suitable means for economically and effectively controlling dust in confinement livestock buildings. Based on the experiences of this study, the following researchable information will be needed before a satisfactory system is developed:

1. The reduction in decay concentration by ionization was found to be feasible; however, to make the system more efficient an optimum system must be designed. The design should include the optimum current-voltage relationship and the location and spacing for the discharge electrodes and collector plate.
2. One of the advantages of charging particles is the capability of directing the particles for collection. Since bacteria are carried on dust particles, it seems possible that air borne diseases could be controlled and kept from spreading from pen to pen in a confinement building by the proper design of an ionization system.
3. Studies are needed to determine more exactly the health aspects of a cleaner confinement building atmosphere with regard to both the animal and the operator.

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APPENDIX A: MEASUREMENTS OF AIR VELOCITY FOR FANS IN AISI

Table A-1. Measurement of exchange air entering each chamber

Louver openings from top to bottom inches	Louver width inches	Measurement of velocity at equal increments along the louver ft/min			Ave.	CFM
	Chamber #1, East Fan					
1.5	16	600	610	625	612	102
1.65	16	200	200	200	200	36
1.5	16	690	750	660	700	116
1.3	16	925	975	950	950	137
					Total	391
	Chamber #1, West Fan					
2.1	16	400	400	400	400	93
2.1	16	420	440	415	425	100
2.0	16	660	650	680	661	147
1.75	16	925	970	1000	963	187
					Total	527
	Chamber #2, East Fan					
1.5	16	700	725	750	725	120
1.5	16	275	300	375	313	52
1.5	16	550	560	620	575	96
1.4	16	1010	1010	1125	1017	160
					Total	428
	Chamber #2, West Fan					
2.0	16	400	500	500	466	104
1.9	16	400	375	385	387	81
1.9	16	615	600	630	615	128
1.7	16	950	900	925	925	180
					Total	493

Table A-2. Measurement of air movement from each circulating fan

Distance from center of fan inches	Measurement of velocity at equal points around the given radius ft/min				Ave.	CFM
		Chamber #1, South Fan				
1.75	900	800	1200	1150	1012	42
2.50	1050	900	1500	1150	1150	80
3.00	1200	1000	1700	1400	1325	80
3.75	1350	1150	1800	1600	1475	163
4.50	1500	1200	2000	1900	1650	223
5.25	1550	1400	1900	2000	1712	273
6.00	1550	1400	1750	1650	1588	292
6.75	1600	1400	1750	1650	1600	334
7.50	100	1350	1500	250	800	186
8.00	100	200	1200	0	375	63
					Total	1736
		Chamber #1, North Fan				
1.75	700	900	800	1000	850	45
2.50	900	900	1000	1050	962	67
3.00	1000	1000	1050	1100	1038	62
3.75	1100	1050	1150	1150	1112	123
4.50	1150	1150	1200	1200	1175	158
5.25	1200	1150	1300	1200	1212	193
6.00	1200	1200	1300	1150	1212	223
6.75	1400	1200	1400	1150	1288	269
7.50	1150	1200	900	1000	1062	248
8.00	0	0	0	0	0	0
					Total	1388

Table A-2 (Continued)

Distance from center of fan inches	Measurement of velocity at equal points around the given radius ft/min				Ave.	CFM
			Chamber #2, South Fan			
1.75	1050	1050	1100	1050	1062	38
2.50	1100	1100	1150	1200	1138	79
3.00	1150	1150	1300	1300	1225	73
3.75	1250	1200	1450	1400	1325	146
4.50	1350	1300	1500	1400	1388	187
5.25	1550	1350	1600	1500	1500	239
6.00	1400	1350	1600	1400	1438	265
6.75	1450	1300	1600	1400	1438	300
7.50	500	500	1500	700	800	186
8.00	0	0	250	0	62.5	10
					Total	1523
			Chamber #2, North Fan			
1.75	700	900	800	1000	850	48
2.50	900	900	1000	1050	962	73
3.00	1000	1000	1050	1100	1038	72
3.75	1100	1050	1150	1150	1112	138
4.50	1150	1150	1200	1200	1175	189
5.25	1200	1150	1300	1200	1212	223
6.00	1200	1200	1300	1150	1212	285
6.75	1400	1200	1400	1150	1288	321
7.50	1150	1200	900	1000	1062	166
8.00	0	0	0	0	0	15
					Total	1530

APPENDIX B: MEASUREMENTS OF AIR VELOCITY FOR FANS AND WIRING SCHEMATIC FOR ENVIRONMENTAL CHAMBER

Table B-1. Measurements of air circulation from duct with fans at 60% and 100% voltage

Voltage (% of 115 V)	Velocity readings at 6 in. intervals along slot ft/min						Ave.	CFM
60	130	140	80	0	0	30	90	76
	110	70	165	130	130			
100	220	240	250	0	0	150	210	178
	280	220	350	300	300			

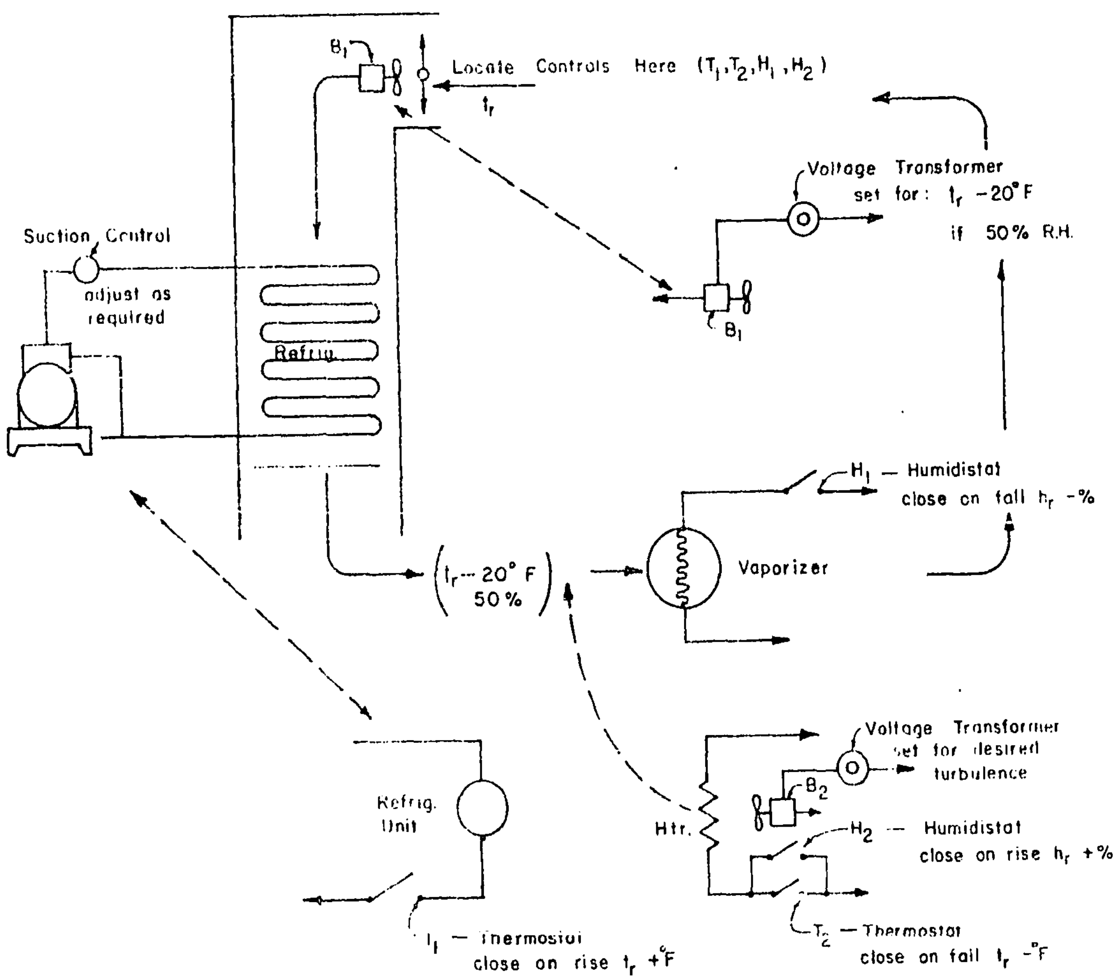

Figure B-1. Wiring schematic for environmental chamber

APPENDIX C: DUST CONCENTRATIONS IN EMPTY CONFINEMENT BUILDING AND SURROUNDING THE BUILDING

Table C-1. Dust concentrations without animals and with fans off, measured in particles ≥ specified diameter per 0.01 ft^3

Date	≥ particle size (μ diameter) .5	1	2	3	5	10
			Chamber #1 AISI			
6-12-72	1850	368	248	44	4	1
6-14-72	590	211	143	38	11	3
6-17-72	1802	291	147	12	1	0
6-18-72	704	224	132	22	0	0
6-21-72	548	170	121	24	6	1
6-22-72	932	338	177	99	3	1
6-26-72	790	427	344	61	9	0
6-28-72	349	106	66	9	3	1
7-26-72	487	215	126	19	4	0
9-20-72	603	289	145	34	3	2
			Chamber #2 AISI			
6-12-72	1620	317	194	39	7	2
6-14-72	465	160	97	16	3	0
6-17-72	1486	251	132	32	6	0
6-18-72	631	194	125	28	4	0
6-21-72	284	110	61	13	2	0
6-22-72	1397	522	370	71	7	0
6-26-72	960	467	332	72	14	2
6-28-72	304	100	57	13	3	1
7-26-72	456	207	133	34	4	1
9-20-72	627	253	128	36	4	0
			Outside AISI			
6-12-72	1446	630	428	85	3	0
6-14-72	546	205	119	23	1	0
6-17-72	1701	283	147	17	1	0
6-18-72	624	182	137	24	1	0
6-21-72	158	49	32	8	1	0
6-22-72	782	162	78	17	4	0
6-26-72	453	221	135	23	4	1
6-28-72	403	131	70	13	3	1
7-26-72	393	221	135	18	4	1
9-20-72	501	210	98	30	9	0

Table C-1 (Continued)

Date	≥ particle size (μ diameter) .5	1	2	3	5	10
Farrowing Building #5 Bilsland Swine Breeding Station						
6-5-72	1281	312	164	14	1	0
6-7-72	1432	434	280	52	8	0
6-9-72	1554	474	282	52	10	0
6-12-72	2988	623	270	47	4	0
6-14-72	404	121	69	14	2	1
6-21-72	388	155	107	28	6	2
6-23-72	531	185	134	35	3	1
7-5-72	406	174	103	24	5	0
7-10-72	913	281	168	38	5	2
7-19-72	255	82	45	11	3	0
7-21-72	876	271	106	14	1	0
7-24-72	411	149	68	8	2	1
7-26-72	271	112	66	19	4	1
Outside Farrowing Building #5 Bilsland Swine Breeding Station						
6-5-72	1194	317	168	21	4	0
6-7-72	1556	388	185	43	9	2
6-9-72	1818	625	251	24	1	0
6-12-72	2294	348	311	19	0	0
6-14-72	556	209	140	36	7	0
6-21-72	312	151	54	16	2	0
6-23-72	1332	296	130	26	3	1
7-5-72	388	140	111	40	7	0
7-10-72	851	254	135	18	5	1
7-19-72	169	65	29	8	3	0
7-21-72	863	247	149	22	3	1
7-24-72	519	192	117	11	0	0
7-26-72	180	56	30	19	0	0

APPENDIX D: DUST CONCENTRATIONS WITH VARIOUS VENTILATION RATES FOR FLOOR FEEDING IN CHAMBER #1

Table D-1. Dust concentrations with ventilation fans off and with floor feeding ground feed in chamber #1, measured in particles $\geq$ specified diameter per 0.01 ft^3

Date	$\geq$ particle size (μ diameter) 0.5	1	2	3	5	10
			Chamber #1			
03-01-73M	7135	2825	1915	834	147	6
03-01-73A	7055	1820	1054	408	53	1
03-02-73	8923	3510	2230	1023	254	5
03-06-73	12195	4775	2270	1515	251	22
03-08-73	4795	2400	1633	691	104	3
03-22-73	6380	3380	2363	1430	288	26
03-23-73	10050	4970	3135	1495	255	9

Table D-2. Dust concentrations with ventilation fans on and with floor feeding ground feed in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	.5	1	2	3	5	10
10-07-72	3417	1630	549	285	124	37
10-09-72	3270	1825	984	588	169	36
10-11-72	3380	1290	1249	936	400	8
10-12-72	978	328	227	97	25	2
10-25-72	2410	994	476	339	39	2
10-26-72	1160	423	357	145	24	0
10-28-72	653	324	219	133	19	8
11-17-72	2255	1141	587	192	30	8
11-20-72	1305	562	357	190	52	4
11-21-72	1615	655	660	482	76	6
11-22-72	5270	1730	1330	610	223	18
12-01-72	1604	474	460	256	51	1
12-02-72	1338	700	397	149	36	3
12-04-72	2585	776	424	121	20	1
12-14-72	4287	1255	955	626	129	11
01-11-73	3640	1855	1180	665	259	34
01-13-73	1243	635	336	154	44	3
01-16-73	1790	950	853	353	94	17
02-02-73	2680	800	476	218	56	0

Table D-3. Dust concentrations with ventilation fans on, circulation fans on with floor feeding ground feed chamber #1, measured in particles $\geq$ specified diameter per 0.01 ft^3

	$\geq$ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #1			
02-10-73	2650	1545	1355	815	53	5
02-11-73M	2255	1056	660	381	81	13
02-11-73A	3090	1600	1093	572	168	10
02-12-73M	2946	1207	621	346	112	4
02-12-73A	4086	2100	1510	728	168	19
02-14-73	1985	798	416	205	45	1
02-15-73	4405	2515	1676	802	217	25
02-16-73	7660	3850	2810	1775	225	7
02-17-73	3660	2553	1220	540	454	28
02-19-73	1365	272	224	146	42	1
02-20-73	1338	705	535	325	89	8
02-21-73	856	362	353	226	20	0
02-27-73	4770	1868	1393	650	10	2
02-28-73M	6265	1415	966	450	100	3
02-28-73A	2591	433	246	110	36	2
03-29-73	1685	990	790	747	149	5
03-30-73	6660	3335	2750	1750	461	146
03-31-73	3045	1300	947	402	95	14
04-04-73	1280	608	375	274	62	7
04-05-73M	1290	667	517	257	24	3
04-05-73A	937	522	423	248	19	4
05-30-73	3266	2130	1450	712	130	7
05-31-73	1395	823	510	311	94	23

APPENDIX E: DUST CONCENTRATIONS FOR VARIOUS FEEDING METHODS IN CHAMBER #1

Table E-1. Dust concentrations with ventilation fans on circulation fans on, and with floor feeding ground feed in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #1			
02-10-73	2650	1545	1355	815	53	5
02-11-73M	2255	1056	660	381	81	13
02-11-73A	3090	1600	1093	572	168	10
02-12-73M	2946	1207	621	346	112	4
02-12-73A	4086	2100	1510	728	168	19
02-14-73	1985	798	416	205	45	1
02-15-73	4405	2515	1676	802	217	25
02-16-73	7660	3850	2810	1775	225	7
02-17-73	3660	2553	1220	540	454	28
02-19-73	1365	272	224	146	42	1
02-20-73	1338	705	535	325	89	8
02-21-73	856	362	353	226	20	0
02-27-73	4770	1868	1393	650	10	2
02-28-73M	6265	1415	966	450	100	3
02-28-73A	2591	433	246	110	36	2
03-29-73	1685	990	790	747	149	5
03-30-73	6660	3335	2750	1750	461	146
03-31-73	3045	1300	947	402	95	14
04-04-73	1280	608	375	274	62	7
04-05-73	1290	667	517	257	24	3
04-05-73	937	522	423	248	19	4
05-30-73	3266	2130	1450	712	130	7
05-31-73	1395	823	510	311	94	23

Table E-2. Dust concentrations with ventilation fans on, circulation fans on and with feeding wet ground feed in troughs twice daily in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	0.5	1	2	3	5	10
			Chamber #1			
07-04-73M	2350	1095	830	381	66	4
07-04-73A	952	328	320	211	47	6
07-05-73M	1790	654	483	288	66	5
07-05-73A	2264	1380	907	358	90	34
07-06-73	1135	745	675	373	44	1
07-07-73	1308	485	258	153	30	4
07-08-73M	2208	340	224	97	15	2
07-08-73A	1202	364	186	90	5	1
07-09-73M	1880	686	461	227	72	5
07-09-73A	1350	575	356	120	28	3
07-10-73	1580	563	384	281	95	6
07-29-73	1020	423	227	152	20	2
07-31-73	765	543	521	323	101	5
08-01-73	1500	572	314	151	47	5
08-02-73M	1715	810	588	319	62	4
08-02-73A	1785	561	326	167	32	3
08-03-73M	1385	559	349	123	8	1
08-03-73A	985	412	169	91	13	1
08-04-73M	2160	887	436	204	62	8
08-04-73A	1115	508	223	88	7	0
08-05-73	979	369	221	100	15	1
08-06-73M	1785	560	359	168	39	3
08-06-73A	1035	359	163	68	9	1

Table E-3. Dust concentrations with ventilation fans on, circulation fans on and with floor feeding pelleted feed in chamber #1, measured in particles $\geq$ specified diameter per 0.01 ft^3

	$\geq$ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #1			
06-21-73	1270	638	354	132	29	4
06-22-73M	1365	520	320	154	22	4
06-22-73A	1365	627	228	97	12	4
06-25-73M	1012	392	265	82	7	1
06-25-73A	955	475	283	83	14	0
06-26-73M	2455	1080	523	157	13	2
06-26-73A	816	370	180	72	6	2
06-27-73	570	275	221	114	25	4
06-28-73M	1290	608	413	204	20	1
06-28-73A	605	315	238	79	2	0
06-29-73M	893	420	297	128	30	5
06-29-73A	1060	472	228	106	21	1

APPENDIX F: DUST CONCENTRATIONS WITH VARIOUS VENTILATION RATES WITH SELF-FEEDERS IN CHAMBER #2

Table F-1. Dust concentrations with ventilation fans off and with self-feeding ground feed in chamber #2, measured in particles $\geq$ specified diameter per 0.01 ft^3

Date	$\geq$ particle size (μ diameter) .5	1	2	3	5	10
			Chamber #2			
03-01-73	8860	4315	2925	1248	229	9
03-02-73M	15700	7490	5480	2635	612	97
03-02-73A	7463	3425	2295	1018	183	7
03-06-73	21550	7850	4975	2095	434	30
03-08-73M	24300	13150	8955	3980	817	146
03-08-73A	10985	5190	2980	1213	182	6
03-22-73	22750	10049	7040	3385	643	114
03-23-73	7640	3185	1920	896	155	3

Table F-2. Dust concentrations with ventilation fans on and self-feeding ground feed in chamber #2, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #2			
10-12-72	4615	1247	902	523	107	6
10-25-72	2946	1566	1153	824	170	23
10-26-72	3840	1440	1376	1045	298	31
10-28-72	4746	1660	1125	675	164	40
11-17-72	10840	5160	4070	2215	845	234
11-18-72	5150	2170	1551	701	231	62
lo-20-72	3600	1375	1090	740	175	45
lo-21-72	2645	1070	622	426	140	5
11-22-72	15600	9285	6746	2130	587	152
12-01-72	9970	5130	3730	1623	419	102
12-02-72	8926	4620	3506	1457	344	82
12-04-72	9900	5720	1750	532	110	6
12-14-72	16450	10625	5580	3170	733	126
01-13-73	4550	2380	1715	990	167	15
01-15-73M	7625	4920	2293	1076	199	18
01-15-73A	10176	4940	2263	1313	376	37
02-02-73	4100	1575	836	566	180	46
02-03-73	2993	1525	940	834	294	56

Table F-3. Dust concentrations with ventilation fans on, circulation fans on and self-feeding ground feed in chamber #2, measured in particles $\geq$ specified diameter per 0.01 ft^3

Date	$\geq$ particle size (μ diameter) .5	1	2	3	5	10
		Chamber #2				
02-10-73	5195	2850	1426	518	149	14
02-11-73M	3765	1036	524	193	39	2
02-11-73A	19810	4030	1550	1000	416	103
02-12-73M	1762	769	406	183	47	0
02-12-73A	4166	1855	1415	758	122	50
02-14-73	3846	1675	1140	641	141	21
02-15-73	7520	4270	2735	1340	285	24
02-16-73	5690	3720	2510	1778	495	147
02-17-73	956	413	244	133	35	4
02-19-73	979	668	602	432	120	18
02-20-73	5530	2225	2133	1331	287	85
02-21-73	1487	1035	647	770	185	13
02-27-73	10336	4521	2631	1293	276	44
02-28-73M	6870	2505	1870	563	147	14
02-28-73A	3925	955	484	230	69	2

APPENDIX G: DUST CONCENTRATIONS FOR VARIOUS FEEDING METHODS IN CHAMBER #2

Table G-1. Dust concentrations with ventilation fans on, circulation fans on and with self-feeding ground feed in chamber #2, measured in particles ≥ specified diameter per 0.01 ft^3

Date	≥ particle size (μ diameter) .5	1	2	3	5	10
			Chamber #2			
02-10-73	5195	2850	1426	518	149	14
02-11-73	3765	1036	524	193	39	2
02-11-73	19810	4030	1550	1000	416	103
02-12-73	1762	769	406	183	47	0
02-12-73	4166	1855	1415	758	122	50
02-14-73	3846	1675	1140	641	141	21
02-15-73	7520	4270	2735	1340	285	24
02-16-73	5690	3720	2510	1778	495	147
02-17-73	956	413	244	133	35	4
02-19-73	979	668	602	432	120	18
02-20-73	5530	2225	2133	1331	287	85
02-21-73	1487	1035	647	770	185	13
02-27-73	10336	4521	2631	1293	276	44
02-28-73	6870	2505	1870	563	147	14
02-28-73	3925	955	484	230	69	2

Table G-2. Dust concentrations with ventilation fans on, air circulation fans on and with self-feeding pelleted feed in chamber #2, measured in particles ≥ specified diameter per 0.01 ft^3

Date	≥ particle size (μ diameter) .5	1	2	3	5	10
			Chamber #2			
06-21-73M	4285	2430	1630	692	200	29
06-21-73A	4435	2515	1420	800	152	20
06-22-73	4480	2570	2240	2120	282	9
06-25-73M	2775	1750	983	518	109	6
06-25-73A	6190	2945	1650	892	191	33
06-26-73M	7395	5405	4825	1430	161	39
06-26-73A	4915	2640	1930	1135	206	13
06-27-73	5955	3325	2720	1455	325	55
06-28-73	10590	5000	1510	610	251	12
06-29-73	3300	1455	984	434	62	3

Table G-3. Dust concentrations with ventilation fans on, air circulation fans on with feeding wet ground feed in troughs twice daily in chamber #2, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #2			
07-04-73M	1520	960	768	449	142	11
07-04-73A	1020	554	472	239	20	3
07-05-73M	4315	2570	1995	1028	107	27
07-05-73A	2265	1380	907	358	90	35
07-06-73M	5735	3125	2340	1275	213	27
07-06-73A	1600	617	512	267	52	9
07-07-73	1309	485	485	153	30	4
07-08-73	2450	278	136	29	3	0
07-09-73	1930	745	597	293	51	5
07-10-73M	5770	3460	1925	1010	184	29
07-10-73A	3560	2030	1450	873	230	30
07-31-73	1905	623	450	283	46	3
08-01-73	3060	1160	736	394	114	7
08-02-73M	5475	2080	1627	660	204	8
08-02-73A	1785	561	327	166	34	4
08-03-73	1785	632	547	299	76	14
08-04-73M	2710	1655	1130	725	174	31
08-04-73A	2195	1510	1330	974	290	26
08-05-73	2330	638	430	297	52	3
08-06-73M	3815	1420	852	530	109	22
08-06-73A	1775	703	523	259	56	14

Table G-4. Dust concentrations with ventilation fans off, circulation fans on and with feeding ground feed twice daily in troughs in chamber #2, measured in particles ≥ specified diameter per 0.01 ft^3

	≥ particle size (μ diameter)					
Date	.5	1	2	3	5	10
			Chamber #2			
08-07-73M	3947	1890	1742	303	59	1
08-07-73A	3150	1495	926	885	166	2
08-08-73M	2255	1375	703	283	105	5
08-08-73A	2350	1305	821	183	26	3
08-09-73	2010	1195	863	577	137	9
08-13-73M	3685	1513	931	531	115	19
08-13-73A	2815	1455	1036	475	81	5
08-14-73M	6683	2210	1525	855	169	30
08-14-73A	1915	1135	1042	460	94	6
08-15-73M	3035	1705	760	307	70	6
08-15-73A	2455	1283	1227	678	131	11
08-16-73M	1528	469	299	207	36	1
08-16-73A	1420	762	430	197	61	7
08-17-73M	1300	417	300	191	65	2
08-17-73A	2005	1015	868	433	74	3
08-20-73	2030	1210	935	320	52	8
08-22-73M	1525	625	448	287	54	2
08-22-73A	1630	815	670	469	123	14
08-23-73M	2955	1590	1390	466	75	4
08-23-73A	3113	2235	1485	897	158	7
08-24-73	3157	1265	745	260	39	3

APPENDIX H: DUST DECAY RATES FOR VARIOUS VENTILATION RATES AND FORMS OF FEED IN CHAMBER #1

Table H-1. Dust concentrations with ventilation fans off and with floor feeding, before feeding, directly after feeding 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	.5μ							1μ						
03-01-73M	7135	-	14245	10064	7130	6505	7055	2825	-	6480	5005	2827	1870	1820
03-01-73A	7055	-	7813	6305	5520	4255	4487	1820	-	2305	1845	1330	849	7063
03-02-73	8923	-	15250	14200	7155	5133	4743	3510	-	5635	4647	2400	1235	1180
03-08-73	4795	-	14200	9658	4530	2365	1765	2400	-	7630	5260	2320	1201	897
01-08-74	5375	6430	9750	5815	1835	853	1096	1505	2930	3610	1785	743	321	372
01-19-74	5745	5130	3560	2940	2625	3450	3140	2340	1880	1345	1195	1035	1455	1270
01-20-74	9140	10300	10950	9745	6610	4160	4210	3900	3820	4450	3960	2455	1465	1590
01-22-74	9555	12400	9500	5650	3105	2795	2435	3615	5370	3215	2195	1290	1185	1010
01-23-74	7925	8010	8575	6995	5810	3320	6755	3710	3890	3225	2890	2255	1925	2840
01-24-74	14200	14500	13950	10250	5255	4015	3600	6680	6380	5465	3970	2325	1530	1800
	2μ							3μ						
03-01-73M	1915	-	4490	3405	1805	1070	1054	834	-	2106	1624	721	367	408
03-01-73A	1054	-	1310	950	633	347	331	408	-	630	368	208	115	110
03-02-73	2230	-	3965	3280	1565	733	679	1023	-	1820	1620	618	241	233
03-08-73	1633	-	6275	4005	1525	741	538	691	-	3537	1985	660	287	228
01-08-74	1045	1550	1705	1000	308	150	199	283	512	511	305	118	41	44
01-19-74	1080	930	580	492	518	812	716	325	270	162	152	170	262	245
01-20-74	2410	2490	2360	1975	1315	702	939	852	744	739	615	345	190	267
01-22-74	2390	3070	2070	1325	765	720	777	1099	1180	668	465	209	137	255
01-23-74	2215	2930	1895	1815	1095	860	1640	801	1060	697	605	362	315	549
01-24-74	4285	4040	3270	2385	1285	865	1090	1555	1570	1105	713	403	222	323

	5μ							10μ						
03-01-73M	147	–	336	252	91	65	53	6	--	37	35	3	1	1
03-01-73A	53	–	99	59	16	1	6	1	--	9	7	0	0	0
03-02-73	254	–	323	196	89	27	33	5	--	39	21	4	0	2
03-08-73	104	–	781	409	99	33	26	3	--	133	77	6	1	0
01-08-74	27	90	74	27	8	4	6	5	5	6	4	1	1	0
01-19-74	44	36	28	15	16	49	74	5	4	3	2	1	8	6
01-20-74	92	126	80	74	46	12	41	8	20	13	17	5	2	3
01-22-74	160	140	95	34	24	16	25	19	27	9	3	2	1	6
01-23-74	192	190	103	64	41	25	76	17	32	16	7	3	2	9
01-24-74	188	262	157	74	31	22	33	24	26	21	14	6	6	2

Table H-2. Dust concentrations with ventilation fans on, circulation fans on, and with floor feeding pellets, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles $\geq$ specified diameter per 0.01 ft^3

	Particles $\geq$ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	.5μ							1μ						
06-21-73	1270	1090	799	891	758	628	1025	638	599	374	362	306	352	478
06-22-73M	1365	1400	1195	710	1175	1055	816	520	724	510	334	646	552	424
06-22-73A	1365	900	1055	895	700	780	984	627	455	439	376	315	386	392
06-25-73M	1012	1400	970	1002	744	1008	873	392	719	602	486	352	424	383
06-25-73A	955	1510	1370	1220	1440	3105	2625	475	709	536	586	754	1530	1225
06-26-73M	2455	3870	2950	1230	3170	1360	978	1080	1920	1480	635	1360	665	425
06-26-73A	816	747	690	580	502	410	712	370	329	290	265	195	161	265
06-27-73	570	1090	817	628	625	505	468	275	518	420	275	238	186	230
06-28-73M	1290	1910	856	738	718	857	574	608	990	461	369	343	365	251
06-28-73A	605	708	865	783	466	860	1210	315	394	382	309	210	523	381
06-29-73M	893	1330	1080	960	753	799	965	420	643	512	407	420	338	488
06-29-73A	1060	2090	1090	1060	1040	2245	1525	472	1070	526	445	555	1135	920
	2μ							3μ						
06-21-73	354	349	225	167	202	192	248	143	185	139	84	70	90	93
06-22-73M	320	507	297	223	488	351	298	154	260	126	114	148	119	86
06-22-73A	228	253	306	253	213	182	282	97	115	89	93	62	42	104
06-25-73M	265	407	354	317	197	253	230	82	205	171	161	85	86	92
06-25-73A	283	459	282	330	504	563	811	83	186	128	117	174	171	310
06-26-73M	523	1430	880	362	932	422	268	157	560	304	138	348	130	104
06-26-73A	180	226	145	141	92	76	135	72	87	70	49	24	25	46
06-27-73	221	332	322	203	119	131	156	114	244	121	105	58	51	71
06-28-73M	413	776	308	269	243	277	159	204	359	189	124	94	106	55
06-28-73A	238	218	254	207	144	393	240	79	95	97	67	48	67	115
06-29-73M	297	458	298	274	223	198	387	128	282	187	177	102	80	167
06-29-73A	228	734	408	204	370	658	738	106	358	182	96	140	245	234

	5μ							10μ						
06-21-73	29	62	23	22	18	11	13	4	10	3	3	1	2	1
06-22-73M	22	84	44	14	17	14	4	4	7	4	2	2	3	0
06-22-73A	12	16	7	14	9	7	8	4	2	1	2	1	1	3
06-25-73M	7	48	57	27	9	6	5	1	7	5	3	1	1	1
06-25-73A	14	39	15	10	12	13	28	0	8	1	3	1	1	1
06-26-73M	13	52	39	18	37	8	14	2	5	9	2	6	1	3
06-26-73A	6	1	1	8	1	1	2	2	6	1	1	0	0	1
06-27-73	25	56	36	27	14	4	10	4	5	6	3	2	0	1
06-28-73M	20	114	25	17	13	19	6	1	9	4	4	2	1	1
06-28-73A	2	9	9	9	5	16	9	0	2	1	2	0	2	0
06-29-73M	30	60	16	59	19	16	20	5	10	3	5	2	2	2
06-29-73A	21	48	22	18	19	39	26	1	3	3	5	2	4	2

Table H-3. Dust concentrations with ventilation fans on, circulation fans on and with floor feeding, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles $\geq$ specified diameter per 0.01 ft^3

	Particles $\geq$ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5µ							1µ						
03-29-73	1685		2050	1710	1433	1019	1775	990		908	807	546	350	755
03-30-73	6660		3705	3357	2370	3460	5595	3335		1685	1620	1070	1240	2120
03-31-73	3045	5590	3155	2400	2207	2045	2245	1300	2460	1595	1163	656	818	1054
04-04-73	1280	2270	1005	914	542	724	1345	608	1020	440	295	197	255	475
04-05-73M	1290	1630	1327	809	950	634	531	667	819	652	418	246	286	269
04-05-73A	937	1490	859	964	583	1417	1028	522	824	378	225	379	725	532
05-30-73	3266	6620	3530	2185	1375	651	682	2130	4320	1647	1070	723	313	336
05-31-73	1395	6070	3840	2395	1117	905	572	823	3190	1975	1465	615	415	245
	2µ							3µ						
03-29-73	790		814	584	339	204	630	747		456	282	193	105	356
03-30-73	2750		1140	1050	825	798	1393	1750		702	604	465	355	482
03-31-73	947	2300	974	802	497	457	770	402	1931	478	386	237	242	451
04-04-73	375	850	278	182	110	137	303	274	464	130	80	61	58	97
04-05-73M	517	676	458	374	133	169	225	257	471	227	127	67	83	103
04-05-73A	423	648	242	545	284	68	372	248	326	126	307	150	380	157
05-30-73	1450	3630	1230	866	513	131	230	712	1610	702	306	251	50	164
05-31-73	510	2170	1685	1160	328	244	90	311	1180	985	737	177	100	39
	5µ							10µ						
03-29-73	149		132	85	49	28	144	5		26	18	4	1	
03-30-73	461		170	132	110	64	85	146		40	30	12	7	
03-31-73	95	463	93	89	62	56	79	14	118	25	18	3	5	
04-04-73	62	127	26	22	11	10	25	7	37	11	7	2	3	
04-05-73M	24	98	39	24	7	19	8	3	24	12	9	2	2	
04-05-73A	19	51	27	20	23	40	28	4	13	7	9	1	1	
05-30-73	130	420	118	75	46	13	33	7	89	39	22	14	3	
05-31-73	94	287	252	119	28	27	12	23	73	49	32	5	4	

APPENDIX I: DUST DECAY RATES FOR VARIOUS VENTILATION RATES WITH IONIZATION IN CHAMBER #1

Table I-1. Dust concentrations with ventilation fans off and with floor feeding, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	.5μ							1μ						
01-08-74	5375	6430	9750	5815	1835	853	1096	1505	2930	3610	1785	743	321	372
01-19-74	5745	5130	3560	2940	2625	3450	3140	2340	1880	1345	1195	1035	1455	1270
01-20-74	9140	10300	10950	9745	6610	4160	4210	3900	3820	4450	3960	2455	1465	1590
01-22-74	9555	12400	9500	5650	3105	2795	2435	3615	5370	3215	2195	1290	1185	1010
01-23-74	7925	8010	8575	6995	5810	3320	6755	3710	3890	3225	2890	2255	1925	2840
01-24-74	14200	14500	13950	10250	5255	4015	3600	6680	6380	5465	3970	2325	1530	1800
	2μ							3μ						
01-08-74	1045	1550	1705	1000	308	150	199	283	512	511	305	118	41	44
01-19-74	1080	930	580	492	518	812	716	325	270	162	152	170	262	245
01-20-74	2410	2490	2360	1975	1315	702	939	852	744	739	615	345	190	267
01-22-74	2390	3070	2070	1325	755	720	777	1099	1180	668	465	209	137	255
01-23-74	2215	2930	1895	1815	1095	860	1640	801	1060	697	605	362	315	549
01-24-74	4285	4040	3270	2385	1285	865	1090	1555	1570	1105	713	403	222	323
	5μ							10μ						
01-08-74	27	90	74	27	8	4	6	5	5	6	4	1	1	0
01-19-74	44	36	28	15	16	49	74	5	4	3	2	1	8	6
01-20-74	92	126	80	74	46	12	41	8	20	13	17	5	2	3
01-22-74	160	140	95	34	24	16	25	19	27	9	3	2	1	6
01-23-74	192	190	103	64	41	25	76	17	32	16	7	3	2	9
01-24-74	188	262	157	74	31	22	33	24	26	21	14	6	6	2

Table I-2. Dust concentrations with ventilation fans off, ionization on, and collectors on, with floor feeding, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5μ							1μ						
02-19-74	6360	7700	6360	5440	2120	1315	488	3160	3370	2860	2535	1000	563	287
02-20-74		8580	6240	5085	1085	943	658		3060	2380	2020	414	330	281
02-21-74		9680	7010	4760	3830	777	1705		2880	2445	1865	1295	263	826
02-22-74		14000	9490	7795	3135	1490	295		4820	4180	3675	1470	543	116
02-23-74		8980	8380	6650	2900	1255	911		3140	2700	1940	1325	598	345
02-25-74		11700	9755	10385	6065	4275	2800		5070	4195	4620	2340	1720	991
02-26-74		12100	6875	6665	3605	3230	2055		5050	2705	2495	1690	1420	926
02-27-74		15000	9810	8785	4265	2475	957		6490	3355	3855	1815	1005	618
	2μ							3μ						
02-19-74	1730	1890	2070	1380	528	336	204	756	732	690	417	141	96	52
02-20-74		1900	1430	990	245	283	187		580	556	257	70	99	56
02-21-74		2300	1675	1090	675	103	743		1060	655	343	204	22	394
02-22-74		3160	2515	2015	556	354	92		1000	1100	755	247	82	73
02-23-74		2420	1895	1275	745	311	213		982	656	390	222	115	98
02-25-74		3670	2515	2685	1020	762	502		1200	882	807	266	182	70
02-26-74		2730	1500	1410	969	635	601		1000	478	432	220	162	177
02-27-74		3550	2115	1990	760	409	309		1460	665	597	217	104	100
	5μ							10μ						
02-19-74	113	76	62	37	10	5	1	14	7	5	4	2	1	1
02-20-74		35	31	23	7	21	5	1	16	7	1	1	2	0
02-21-74		82	46	24	11	2	22		8	6	4	1	0	3
02-22-74		163	107	64	25	11	9		26	15	13	2	0	2
02-23-74		129	76	44	25	12	11		12	9	5	4	1	1
02-25-74		144	108	74	17	14	9		13	12	5	0	1	0
02-26-74		101	45	33	29	12	22		16	10	3	3	1	2
02-27-74		125	46	40	19	5	9		23	5	4	1	1	0

Table I-3. Dust concentrations with ventilation fans off, ionization on, and collectors off, with floor feeding, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5µ							1µ						
01-29-74	4030	7710	5165	3845	2325	1975	802	1395	3060	1945	1575	873	783	408
02-05-74	1450	3550	7180	6630	2425	1430	538	392	2190	2270	2210	1195	713	204
02-06-74	3260	7350	6165	4425	2272	1165	1130	1420	3540	2145	1480	861	418	390
02-12-74	2560	5850	2995	3310	1490	1060	791	1140	2580	1165	1320	513	391	259
02-13-74	1615	2930	2460	2090	905	580	698	729	1250	1080	825	374	294	222
02-15-74	6130	5350	3910	2205	1050	1116	1125	2750	2730	1450	1040	506	356	383
02-16-74	3925	4410	3170	3130	1135	390	208	1650	1460	1645	1120	604	152	53
02-17-74	2160	8730	4930	3975	1795	464	864	952	3290	1975	1660	432	152	550
	2µ							3µ						
01-29-74	1071	1780	1135	924	469	820	255	359	559	397	307	148	123	71
02-05-74	194	1630	1490	1095	673	311	107	59	497	462	347	198	66	27
02-06-74	1105	2230	1200	836	517	176	209	450	732	371	245	154	66	62
02-12-74	779	1330	701	801	180	240	134	344	507	254	282	64	92	42
02-13-74	457	750	724	491	250	185	148	233	328	306	132	63	49	47
02-15-74	2055	1560	678	543	212	220	176	785	565	153	158	87	46	46
02-16-74	1175	982	707	471	236	61	16	441	330	188	109	44	8	7
02-17-74	672	1820	1380	1465	251	64	290	289	480	431	363	117	22	52
	5µ							10µ						
01-29-74	69	74	35	38	15	18	6	7	10	5	4	9	2	1
02-05-74	12	105	69	26	13	13	7	1	14	10	8	1	1	1
02-06-74	56	97	46	27	15	7	14	16	23	9	9	4	1	1
02-12-74	36	78	36	32	8	10	12	2	15	7	7	1	1	1
02-13-74	39	62	46	28	6	3	4	3	13	11	3	1	1	0
02-15-74	108	87	17	15	5	5	5	6	9	2	1	1	1	1
02-16-74	59	39	16	5	2	2	5	7	1	1	1	1	1	0
02-17-74	32	67	56	37	14	1	3	1	8	4	1	1	1	1

Table I-4. Dust concentrations with ventilation fans on and with floor feeding, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

Date	Particles ≥ specified diameter													
	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5μ							1μ						
04-20-73M	7820		4225	2900	1540	1095	1640	4740		1930	1380	835	528	784
04-20-73A	5790		4975	2285	1325	1088	1515	4060		2970	795	590	482	895
04-26-73M	7620		2290	2900	1440	1355	1295	4730		1295	1110	819	604	588
04-26-73A	2540		1515	1540	1035	1626	1590	1060		879	467	622	1120	819
05-12-73	8770		3715	3465	1375	443	1285	5720		2175	1735	649	366	547
05-16-73	4840		3300	2745	1560	1085	2075	2890		1570	1365	779	449	1130
05-25-73	16900		7975	5415	2475	1880	2280	10900		3890	3010	1502	910	1205
12-12-73	3400	3210	1457	1089	851	733	1137	1405	1380	692	349	261	158	543
12-14-73	2635	2310	945	736	878	622	697	1305	1312	630	497	233	252	336
12-19-73	2665	2392	1815	1800	1530	1406	1430	680	740	520	445	383	330	465
12-20-73	2310	2260	1988	1278	836	868	844	670	643	464	275	221	278	351
	2μ							3μ						
04-20-73M	3060		1375	868	405	250	365	1570		803	478	116	45	146
04-20-73A	2150		1465	547	400	211	697	885		771	288	169	86	357
04-26-73M	3770		904	757	627	464	239	1290		568	409	329	346	135
04-26-73A	716		677	396	334	891	654	469		441	186	128	498	512
05-12-73	4550		1625	1210	457	258	444	2880		760	647	247	130	254
05-16-73	2550		1220	974	530	291	700	1700		748	501	363	163	317
05-25-73	6980		3205	2465	506	592	986	3730		1530	1155	263	260	486
12-12-73	705	1110	417	223	167	129	412	323	670	295	124	80	56	165
12-14-73	975	972	445	298	174	145	221	413	559	196	154	100	123	119
12-19-73	374	578	240	198	230	156	269	170	327	115	88	58	51	114
12-20-73	350	397	276	177	116	163	185	160	245	113	106	51	73	83

	5µ							10µ						
04-20-73M	470		148	83	17	2	22	73		39	18	1	1	1
04-20-73A	196		110	43	32	11	32	58		37	7	4	2	4
04-26-73M	277		105	103	105	49	27	61		38	22	19	20	15
04-26-73A	123		55	34	34	85	55	18		16	9	4	30	8
05-12-73	469		218	119	60	35	48	102		27	25	15	6	10
05-16-73	559		149	88	56	28	44	87		31	25	11	5	9
05-25-73	798		330	225	39	43	82	137		71	44	11	9	18
12-12-73	71	155	70	38	18	8	29	20	31	15	6	5	3	8
12-14-73	106	116	51	31	33	21	20	22	23	9	4	2	3	2
12-19-73	34	67	34	20	16	8	14	7	13	7	6	4	0	2
12-20-73	35	72	21	17	10	20	13	8	14	4	4	2	2	1

Table I-5. Dust concentrations with ventilation fans on, ionization on, collectors on and with floor feeding ground feed, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5μ							1μ						
12-03-73	3090	8320	3985	1900	1680	1330	467	1195	3420	1325	1030	732	509	153
12-07-73	3970	17430	5100	3995	2050	625	900	1820	6970	2130	1885	880	203	760
12-08-73	4860	8300	2420	1230	747	615	1115	3105	3580	975	541	284	228	540
12-10-73	5190	9540	2700	1295	691	396	1105	2750	3540	1175	769	297	161	710
12-11-73	2665	9230	3405	1670	1735	815	1015	1305	3900	1145	853	769	315	303
	2μ							3μ						
12-03-73	637	2140	894	597	337	401	107	352	850	418	241	172	150	50
12-07-73	1190	4030	1600	1050	540	92	635	700	2300	1070	485	194	37	430
12-08-73	228	1760	643	345	196	126	353	1185	940	227	142	84	61	243
12-10-73	1372	2000	502	366	245	84	504	505	916	267	233	116	54	229
12-11-73	865	2010	700	479	419	159	171	589	910	268	174	154	66	67
	5μ							10μ						
12-03-73	93	170	69	37	16	22	3	15	13	9	4	5	4	1
12-07-73	78	364	127	82	31	8	50	18	33	17	9	7	2	11
12-08-73	170	80	35	30	15	9	38	22	10	2	3	6	4	9
12-10-73	121	138	60	35	29	9	46	7	19	7	9	8	1	10
12-11-73	130	142	45	30	32	10	4	32	18	10	5	7	1	1

Table I-6. Dust concentrations with ventilation fans on, ionization on, collectors off and with floor feeding ground feed, before feeding, directly after feeding, 15, 30, 60, 90, and 120 minutes after feeding in chamber #1, measured in particles ≥ specified diameter per 0.01 ft^3

	Particles ≥ specified diameter													
Date	Before	0	15	30	60	90	120	Before	0	15	30	60	90	120
	0.5µ							1µ						
11-26-73	3925	7520	2375	1670	800	1125	1122	2085	2890	870	705	325	369	406
11-29-73	1690	8170	2450	1730	924	452	391	594	3520	1150	799	418	204	126
11-30-73	1215	5150	3205	2185	1495	939	975	451	2320	1630	1325	848	485	284
12-01-73	2350	4770	1635	1470	892	659	620	916	2210	705	550	385	170	303
12-02-73	1545	7010	2975	1745	1015	514	985	682	3040	1360	632	358	239	422
	2µ							3µ						
11-26-73	1585	1690	619	343	245	214	245	861	647	237	128	108	83	70
11-29-73	501	1810	702	345	302	127	80	233	870	298	140	89	40	53
11-30-73	306	1610	1095	938	547	349	219	138	883	377	324	237	146	92
12-01-73	487	1380	375	460	294	102	204	260	627	192	182	128	36	100
12-02-73	563	2000	982	448	233	132	205	338	1070	758	179	112	60	80
	5µ							10µ						
11-26-73	45	86	30	22	26	18	17	10	7	4	4	1	2	4
11-29-73	21	57	60	27	29	7	5	1	34	12	9	3	3	1
11-30-73	39	179	77	83	64	36	25	1	13	17	18	14	5	1
12-01-73	38	104	37	27	18	8	20	4	15	13	8	4	1	7
12-02-73	74	176	80	33	10	6	9	5	31	14	5	2	1	1

APPENDIX J: DUST DECAY RATES FOR VARIOUS AIR CIRCULATION RATES, HUMIDITY LEVELS, AND IONIZATION LEVELS IN ENVIRONMENTAL CHAMBER

Table J-1. Environmental chamber, fans off, ionization off, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 4 (Cont.)			Run 5		
2080	830	26	2660	1010	41	2170	710	21	6180	2320	141	884	129	0	1840	600	22
1610	690	24	2080	780	28	1850	625	19	5250	1900	134	827	89	1	1470	497	17
1439	617	22	1910	673	25	1680	500	16	4490	1670	91	727	123	0	1530	436	17
1420	489	25	1670	605	15	1550	466	6	4150	1560	69	746	80	2	1238	346	15
1290	508	25	1720	595	13	1530	413	5	3730	1300	69	765	99	0	1263	345	13
1160	547	18	1546	462	15	1320	309	7	3700	1220	44	659	85	0	1211	283	12
1210	506	24	1516	452	13	1230	315	6	3370	1110	46	660	83	0	1026	294	11
1110	398	10	1424	425	13	1160	277	5	2870	880	33	675	62	0	1010	256	14
960	322	11	1287	361	4	1010	228	5	2770	869	30	614	83	0	862	197	4
771	321	6	1237	342	11	940	224	7	2670	699	24	592	64	0	916	200	5
829	253	13	1135	354	9	975	205	2	2510	685	5	628	56	0	909	171	0
851	242	5	1115	301	9	865	168	2	2060	549	15	525	42	0	870	144	4
688	231	4	1066	230	3	919	162	2	1970	472	17				751	127	1
648	180	4	1056	237	3	880	165	4	1920	415	11				683	104	2
705	198	5	1025	248	4	750	143	1	1830	369	13				625	121	2
614	160	1	970	145	4	762	148	5	1550	389	6				519	70	1
652	165	4	815	186	2	853	141	2	1510	343	4				552	94	2
504	151	2	801	183	5	608	111	2	1440	313	5				603	93	0
553	106	3	709	127	3	707	82	0	1390	278	5				514	65	3
528	112	4	697	142	6	589	92	1	1360	250	4				418		
447	84	1	612	117	2	615	63	0	1270	240	3						
452	120	2	644	102	2	642	66	1	1210	202	2						
369	65	0	644	118	0	524	82	2	1120	198	4						
			602	124	0	511	69	0	1040	188	3						
			552	83	0	433	68	1	985	160	1						
			520	100	0	437	67	0	1054	166	1						
			516	78	2				995	150	2						
			479	88	1				922	134	2						
			472	72	0				962	121	0						
									972	116	0						

Table J-2. Environmental chamber, fan 60%, ionization off, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
4850	1270	47	2560	1060	57	2710	1100	54	1750	588	45	2780	874	56
3160	860	26	2060	854	32	1850	729	50	1080	419	18	2120	676	37
2760	710	18	1530	596	25	1540	541	39	962	297	18	1940	624	27
2340	610	16	1400	498	4	1240	508	35	729	241	0	1680	461	22
2120	529	2	1110	356	13	1155	397	10	607	221	3	1410	359	4
1870	422	5	970	357	3	989	381	11	586	156	4	1104	281	2
1530	244	0	1240	454	9	772	303	15	556	152	2	1025	237	3
1250	141	0	1320	474	17	747	260	8	484	110	3	945	210	3
970	78	0	1670	539	7	656	201	3	383	91	0	813	200	1
886	63	1	1480	519	8	550	203	6	323	94	1	806	165	0
905	60	0	1730	518	7	499	159	2	380	79	0	822	140	3
837	59	0	1710	562	5	540	162	0	334	63	1	766	107	0
865	43	0	1430	455	4	461	122	1	327	71	0	728	99	0
768	26	0	1450	390	5	448	103	0	317	46	1	708	81	0
673	19	0	1420	397	0	434	90	1	297	35	0	653	70	0
569	13	0	1250	360	2	390	82	1	304	36	0	621	64	2
581	8	0	1150	333	1	378	75	2	267	30	0	592	63	0
590	9	0	1060	230	2	367	72	2				618	57	0
592			1020	212	1	328	63	0				571	39	0
			1020	191	0	360	62	2				582	40	0
			1020	187	0	339						515	36	0
			830	150	1							522	26	0
			790	139	0							481	36	0
			823	125	0							455	25	0
			702	124	0									
			682	107	0									
			677	98	1									
			653	71	0									
			614	68	0									
			640	82	0									
			622											

Table J-2 (Continued)

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 6			Run 7			Run 8			Run 9			Run 10		
2240	801	90	3710	1610	143	2770	1060	84	4880	2110	74	3160	1560	62
1810	636	46	3160	1310	79	2290	816	67	5020	2060	55	2590	1180	36
1460	526	30	2620	1080	41	1880	803	43	4190	1800	41	2230	990	28
1260	386	12	2070	870	53	1660	710	40	4230	1620	40	1870	810	23
1043	352	16	1920	669	28	1580	681	40	3530	1360	36	1650	629	15
829	300	8	1890	654	23	1510	531	21	3140	1130	21	1590	556	9
753	251	3	1770	568	8	1270	512	14	2770	1110	27	1510	424	11
672	184	2	1620	476	14	1180	418	23	2710	880	24	1240	381	4
619	154	5	1610	405	16	1020	462	16	2480	830	12	1040	331	2
602	137	1	1440	367	7	1070	339	13	2330	710	16	1050	278	6
534	101	3	1250	307	7	940	348	8	2200	645	7	930	280	2
523	116	2	1120	286	6	770	301	8	1999	553	10	850	236	5
565	90	2	1140	204	2	676	219	4	1900	515	5	841	184	2
433	91	3	1140	192	3	547	184	4	1910	510	8	749	181	0
505	80	1	1080	191	2	609	166	8	1680	430	0	647	150	1
411	64	0	950	154	4	533	195	3	1610	390	0	725	152	0
456	68	1	1010	161	2	532	190	6	1540	330	0	685	128	1
379	50	0	940	158	1	450	143	1	1470	340	0	605	119	2
			890	152	1	435	113	0	1451	283	3	588	106	0
			914	138	2	467	107	0	1334	273	2	581	84	0
			909	111	1	366	103	1	1323	253	3	502	92	0
			908	105	0	410	83	2	1249	250	1	466	87	0
			851	96	0	403	94	1	1316	241	2	499	65	1
			842	107	0	347	68	2	1161	220	0	489	74	0
			769	76	0	354	64	2	1137	239	3	429	59	2
			832	70	1	297	70	0	1122			375	49	0
			801	85	0	305						389	62	0
			784	68	0							327	53	0
			723	63	0							381		
			696	70	0									
			684											

Table J-2 (Continued)

.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ
Run 11			Run 12			Run 13			Run 14			Run 15		
4570	1310	47	7790	3110	124	2860	1400	124	3460	1590	148	6290	2480	190
3150	1150	29	4650	1560	49	2030	1070	93	2670	1150	86	5180	2060	127
2620	1010	31	3480	1290	45	1770	800	60	2050	809	38	4450	1820	104
2500	810	14	3090	1070	16	1430	657	50	1470	596	54	4030	1620	66
2020	700	13	2680	830	22	1120	533	33	1255	475	24	3410	1310	41
1660	568	10	2380	710	7	957	427	20	1049	364	31	3010	1120	33
1540	478	5	2110	610	3	795	310	19	844	312	18	2430	920	19
1450	406	6	1790	551	5	685	333	13	840	231	16	2130	829	20
1370	353	7	1800	456	4	652	229	3	714	242	10	1780	657	19
1210	271	2	1640	406	6	509	212	7	664	170	13	1440	574	10
1130	304	2	1450	344	6	426	148	10	560	171	5	1320	436	2
1010	232	3	1240	289	4	437	141	10	459	120	4	1200	430	7
900	177	0	1200	285	1	450	141	3	459	114	6	1100	370	2
800	179	1	1210	232	4	412	125	1	398	100	7	950	295	4
860	155	1	980	234	1	293	98	2	411	95	3	843	262	2
689	113	0	1020	191	3	287	87	0	347	88	0	774	209	1
629	107	0	910	145	1	348			364			713	168	1
715	109	0	851	138	1							656	169	1
620	90	0	848	132	0							590	166	0
619	81	0	691	150	0							602	144	1
598	63	0	775	95	0							466	117	0
499	54	0	693	119	1							505	112	0
468	73	0	568	102	0							462	80	0
391	61	0	567	89	3							413	87	0
452	43	0	608	83	0							368	67	0
429	50	0	553	70	0							345	68	0
404	50	0	551	76	0							358	59	1
349	28	0	543	69	0							290		
326	33	0	505	61	0									
383			466											

Table J-2 (Continued)

Run 16			Run 17			Run 18			Run 19		
.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
3220	1620	104	5660	2260	118	4590	2090	65	4870	2240	129
2650	1220	64	4990	1800	118	3810	1720	74	4150	1970	61
2410	1240	54	4270	1620	64	3640	1510	43	3820	1780	55
2260	1080	45	3620	1350	37	2860	1390	35	3450	1430	47
1940	980	65	2980	1210	37	2620	1050	35	3070	1240	41
1540	810	43	2630	980	23	2200	860	21	2290	1020	25
1630	793	23	2480	860	10	1820	697	15	1960	840	13
1420	640	16	1980	713	8	1600	584	12	1750	706	12
1180	566	20	1760	618	7	1620	540	6	1430	617	18
990	531	16	1670	461	12	1500	418	8	1310	510	9
984	498	20	1400	409	7	1120	371	11	1130	501	9
872	399	10	1300	392	10	1130	383	7	960	389	7
838	410	5	1090	317	1	1070	300	10	931	364	7
769	330	10	1160	282	5	970	278	3	902	342	7
668	317	8	930	258	1	810	211	4	742	273	8
611	263	6	810	235	2	766	189	1	744	247	4
536	239	4	725	185	1	647	189	0	652	245	2
484	219	7	642	188	2	631	193	0	663	189	2
498	216	9	575	151	0	560	159	0	628	185	1
471	170	0	495	129	0	535	112	0	455	160	2
385	150	0	572	130	1	484	89	0	528	142	0
393	150	0	466	104	0	458	90	0	471	144	1
360	134	0	417	87	0	421	83	5	399	127	2
413	139	0	430	84	0	399	82	0	346	100	2
			467	82	1				375	70	0
			423	70	1				366		
			312	90	0						
			310	67	0						
			328								

Table J-3. Environmental chamber, fan 100%, ionization off, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5µ

.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ	.5µ	2µ	5µ
Run 1			Run 2			Run 3			Run 4			Run 5		
7200	2950	177	5250	2170	113	5870	2280	113	3900	1420	52	4370	1760	67
3600	1050	45	2340	680	43	2990	736	43	1830	390	8	2670	610	11
1740	357	9	1330	290	5	1350	272	10	929	190	3	1460	262	4
930	150	3	793	107	7	672	111	3	675	110	2	959	123	1
615	58	0	475	47	1	502	47	1	394	48	1	585	61	2
410	28	0	348	28	1	316	33	3	330	32	0	449	36	0
329	25	0	234	18	0	280	11	4	237	26	0	353	19	3
245	14	0	224			158			197			237	12	0
197												248	4	0
												207		

.5µ	2µ	5µ
Run 6		
4880	1940	109
2690	728	25
1340	323	7
890	161	3
650	79	0
544	80	1
453	32	1
374	31	0
165	14	0
153		

Table J-4. Environmental chamber, fans off, ionization on, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
3130	1200	107	3900	1610	109	2490	1010	61	5380	2370	168	7510	2688	220
2380	799	31	3000	1420	83	1870	779	47	4230	1710	107	4860	1820	123
1380	506	29	2730	1140	70	1060	444	21	2460	1020	43	3310	1180	85
900	346	16	2050	867	39	745	245	11	1700	753	32	2940	1060	64
646	235	4	1650	634	22	619	247	5	1190	472	20	2250	828	28
453	140	4	830	325	5	538	138	2	782	303	12	1580	584	16
233	98	4	729	253	15	374	99	2	475	211	14	1110	354	8
235	61	1	455	125	7	221	64	2	397	118	4	940	291	13
117	39	0	311	80	5	182			280	104	1	801	190	5
			201	40	1				220			641	162	3
			178									455	111	5
												410	95	1
												351	70	0
Run 6			Run 7			Run 8			Run 9			Run 10		
3440	1320	60	4290	1500	82	7340	4280	372	6850	4980	255	6840	4750	325
2510	1118	40	2340	830	41	7310	2040	153	7650	2710	123	10040	3940	130
1935	781	26	1640	506	28	3000	1000	58	4320	1340	39	5340	1880	77
1812	568	30	1180	361	10	1610	531	22	2260	732	15	2440	940	35
1213	418	17	750	242	9	949	295	11	930	372	3	1360	415	7
817	327	14	681	218	13	494	172	3	524	157	5	737	167	10
659	213	9	613	179	8	278			277			361		
578	157	5	401	94	3									
418	97	2	266											
263	78	0												
210	53	3												
205														

Table J-4 (Continued)

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 11			Run 12			Run 13		
5890	4920	309	3670	4630	238	6500	2650	182
8250	3200	141	7880	3180	104	5090	2030	134
4420	1500	65	4490	1650	41	3500	1240	100
2440	906	31	2310	941	29	2630	639	34
1170	444	7	1150	458	6	1010	439	15
698	198	5	578	207	3	843	176	8
390	121	2	321			338		
176								

Table J-5. Environmental chamber, fans 60%, ionization on, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
	Run 1			Run 2			Run 3			Run 4			Run 5	
2890	1090	103	2490	1000	71	2690	1290	88	1810	731	66	1300	518	24
1800	637	46	1540	530	41	1580	737	42	1160	387	25	773	305	9
1090	355	19	844	323	19	988	380	31	644	219	6	457	176	5
588	222	12	510	199	13	590	281	22	440	108	1	274	85	3
391	139	10	416	124	8	408	168	9	281	64	1	187	55	0
332	100	5	273	83	3	313	120	5	212	47	0	111	43	0
191	53	2	200	62	1	211	67	1	124					
			123			137								
	Run 6			Run 7			Run 8			Run 9			Run 10	
1470	723	30	1620	773	28	1560	672	31	4060	1650	96	8470	3230	133
955	403	6	950	394	15	690	318	8	2513	880	39	5900	2400	93
550	212	4	696	247	8	456	186	0	1571	549	24	4040	1450	55
337	127	4	499	134	7	277	108	1	1044	369	11	2630	870	22
215	82	0	397	81	1	210	79	2	820	249	10	1868	594	9
147	43	0	240	59	0	133			586	174	6	1324	350	17
			255	31	0				487	124	2	861	258	4
			119						342	98	0	634	133	3
									254	66		477	98	1
												246	52	1
												229		

Table J-6. Environmental chamber, fans 100%, ionization on, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
3050	960	33	2290	689	20	3890	1500	117	5440	2100	117	4140	1610	71
1140	211	6	720	182	4	1570	416	14	2060	590	22	1800	446	8
405	73	2	290	66	1	580	119	4	792	166	3	577	98	3
134	14	0	129	18	0	240	36	0	366	53	0	225	34	0
						146	8	0	248	17	0	131	11	0
									91	9	0	84	2	0
Run 6			Run 7			Run 8			Run 9					
2820	1010	41	2420	921	38	6120	2050	17	7080	2710	109			
1272	311	6	775	153	5	2320	565	6	3110	898	26			
520	78	1	352	54	0	860	169	0	1305	247	5			
189	23	0	171	10	0	344	48	0	486	74	0			
115	9	0	99	7	0	217	14	0	267	27				

Table J-7. Environmental chamber, fan off, ionization off, RH = 85%, temperature = 80°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 1 (Cont.)			Run 2			Run 3			Run 4		
7330	2400	155	1070	183	2	1770	530	23	1470	530	16	1460	518	18
5580	2030	146	1053	163	1	1180	480	12	1230	495	10	1250	480	15
5080	1850	132	1085	168	3	1042	396	24	1170	408	10	1230	450	9
4840	1670	107	963	184	2	879	337	17	1066	395	8	1200	379	9
4540	1530	82	939	170	1	1018	301	13	1014	373	3	1100	362	11
4040	1390	60	928	135	1	898	322	8	1112	366	7	1000	302	5
3460	1240	58	924	138	4	832	331	9	969	308	9	890	291	7
3150	1000	40	972	127	1	763	242	8	955	300	11	902	247	7
2710	920	34	804	130	1	796	286	2	828	268	4	842	248	5
2550	898	29	865	125	2	717	243	7	899	254	9	801	217	2
2470	759	35	826	136	2	661	233	4	763	225	2	817	203	4
2270	737	27	863	119	1	626	211	10	730	215	8	794	191	5
2290	698	21	864	85	0	667	179	5	667	195	4	705	179	1
2230	621	26	773	104	5	635	166	9	710	189	4	735	188	3
2150	624	12	732	89	2	553	163	3	626	163	3	711	156	1
1910	553	24	679	94	2	560	135	1	694	180	0	694	152	4
1840	503	19	802	102	0	335	146	2	695	166	1	682	119	1
1870	449	10	745	105	3	483	107	2	658	154	3	559	102	0
1640	449	9	762	102	2	488	110	0	611	136	0	639	105	1
1750	389	11	738	67	0	477	98	2	509	144	0	597	106	1
1670	419	4	695	112	3				522	123	3	563	106	0
1690	379	4	697	96	0				533	131	3	584	92	0
1470	376	5	700	79	0				492	125	0	622	90	2
1440	384	6	677	79	0							571	97	0
1540	314	4	730	74	2							484	76	0
1370	329	6	674	73	0							495	98	0
1390	300	7	627	83	0							445	85	0
1520	239	0	664	69	0									
1260	259	2	594	69	1									
1130	221	8	602	67	0									
1124	208	8	519	54	0									
1229	196	3	591	61	0									
1034	179	0												

Table J-7 (Continued)

Run 5			Run 6			Run 7			Run 8			Run 8 (Cont.)		
.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
1240	335	19	1090	296	11	1230	401	16	2570	820	19	735	122	0
1080	360	8	880	290	6	1070	321	7	2650	790	26	786	131	0
963	318	9	747	293	7	870	302	2	2350	818	27	826	130	0
1043	284	10	721	239	14	761	259	9	2210	662	13	737	112	0
938	259	9	742	236	3	806	261	9	2030	626	11	662	129	6
963	224	13	692	216	5	726	208	5	2060	609	5	814	94	1
888	237	4	708	136	6	752	214	2	1770	552	9	665	127	0
804	196	3	542	199	6	675	206	3	1850	547	13	674	115	0
836	165	1	608	148	3	678	198	3	1850	518	10	702	89	0
675	153	1	516	152	2	549	224	3	1600	480	5	554	79	0
704	157	2	544	125	4	640	168	3	1660	435	6	643	91	0
838	196	2	607	135	3	610	183	4	1400	369	3	604	83	0
815	215	2	520	100	0	508	146	0	1470	338	4	607	82	0
738	200	6	517	108	1	573	119	4	1370	339	4	525	83	1
757	143	3	452	105	5	555	143	1	1330	297	1	633	82	0
711	165	5	442	111	2	479	122	2	1190	354	1			
753	151	3				500	116	4	1200	265	1			
665	162	1				494	119	1	1210	248	5			
584	130	6				445	110	1	1120	257	2			
593	121	0							1120	230	1			
577	113	9							940	255	4			
610	106	0							996	204	1			
542	89	1							953	176	1			
534	107	1							1067	260	0			
510	93	0							958	219	1			
616	75	2							925	206	1			
508	89	1							888	180	2			
503	59	5							946	191	1			
495	62	0							824	160	0			
426	60	0							902	149	0			
439	65	0							818	164	1			
									759	132	1			

Table J-7 (Continued)

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 9			Run 9 (Cont.)			Run 10			Run 11			Run 12		
1330	530	15	461	70	1	2401	778	18	2200	800	28	2370	910	35
1340	550	12	480	62	2	2134	591	18	1900	717	16	2020	785	19
1340	413	13	529	69	0	1934	560	18	1580	564	11	1990	738	10
1180	415	7				1760	480	7	1330	474	18	1940	611	10
1170	380	13				1710	440	8	1241	407	11	1810	552	11
1040	347	6				1550	330	6	1122	343	11	1500	503	7
1073	260	6				1452	346	13	1014	337	12	1540	461	10
967	294	4				1320	300	7	881	299	9	1310	369	5
884	263	11				1213	269	4	781	238	6	1280	325	4
951	259	2				1134	220	7	697	186	4	1160	302	2
828	244	3				1033	182	6	636	220	2	1020	293	2
873	244	4				1015	209	3	591	183	5	989	267	3
771	231	3				883	173	1	617	190	4	927	255	5
905	183	3				708	129	0	521	149	4	901	237	4
774	201	6				796	127	1	574	134	3	806	206	1
717	169	1				807	139	3	489	138	4	830	181	1
756	174	2				819	110	2	438	102	2	810	195	1
722	183	0				691	90	1	463	130	2	691	168	1
703	154	2				581	87	3	383	101	0	754	145	0
661	114	7				583	84	0	331	91	1	626	141	0
689	116	0				543	86	1	409	79	0	678	131	1
665	128	0				513	68	1	416	77	1	685	113	1
626	100	1				493	64	0	354	69	0	599	101	0
614	114	0				528	60	1				550	132	1
634	121	0				479	59	0				586	91	0
595	106	2				431	51	0				588	89	1
571	111	2				467	48	4				571	68	1
523	96	0				491	52	1				454	63	0
556	72	1				381	54	1				491	67	0
508	81	1				377	45	0				477	48	0
500	74	0				427	52	1				466	62	0
447	79	0				353	35	0				459	58	0
510	75	1				354	32	0				438	57	1
												454	54	0

Table J-8. Environmental chamber, fan 60%, ionization off, RH = 85%, temperature = 80°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
2220	970	29	2930	981	34	2190	920	21	2230	879	28	3320	1600	56
2170	750	22	1990	651	11	1870	543	17	1940	633	19	3720	1410	55
2010	650	12	1740	470	4	1310	421	15	1560	491	17	3190	1230	36
1771	619	6	1420	377	2	1060	291	10	1270	398	13	2840	1007	16
1520	510	4	1110	247	1	820	200	1	1120	286	2	2240	765	13
1380	319	3	961	180	2	622	146	1	968	274	3	1700	663	13
1288	362	1	616	162	2	612	86	0	606	207	1	1440	522	4
1147	289	0	553	116	1	444	64	2	532	180	3	1290	408	11
967	214	2	435	126	1	414	60	2	491	146	0	1170	462	8
957	220	0	337	75	0	348	37	0	307	103	1	1082	304	4
830	167	0	292			314			344	97	1	872	200	1
833	205	0										585	154	1
698	112	0										524	121	1
745	112	1										416	115	2
627	103	0										324	69	0
647	104	0										291		
579	78	0												
532	98	0												
572	74	0												
535	54	0												
360	63	0												
428	40	1												
381	46	0												

Table J-8 (Continued)

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 6			Run 7			Run 8			Run 9			Run 10		
3110	1150	36	2160	662	6	6400	2430	136	5130	2010	130	4370	1940	92
2040	729	8	1270	421	3	5630	2040	102	3790	1490	124	3210	1440	47
1380	450	9	960	318	4	4410	1530	56	3200	1140	62	2530	1090	34
1050	308	1	691	211	1	3700	1250	46	2450	991	45	2060	886	21
862	225	2	576	135	0	3170	1020	28	2180	800	32	1670	661	13
630	146	3	414	101	1	2560	819	11	1810	704	24	1210	417	3
498	108	2	394	82	1	2380	650	13	1560	511	20	1003	414	4
427	108	0	292			2090	566	15	1416	466	7	991	285	17
338	64	0				1900	487	5	1000	310	12	982	332	4
304						1550	347	8	865	314	9	847	187	6
						1360	280	4	801	240	7	616	140	0
						1670	420	7	707	197	7	499	103	0
						1207	350	4	618	150	5	431	94	1
						1063	228	4	432	134	5	362	67	1
						966	170	3	365	125	2	317	40	0
						843	153	2	377					
						643	121	0						
						608	83	2						
						586	70	0						
						477	47	0						
						457	49	1						
						419	40	1						
						433	46	0						
						442	39	0						
						374	31	0						
						347								

Table J-8 (Continued)

.5μ	2μ	5μ	.5μ	2μ	5μ
Run 11			Run 12		
3780	1710	63	2470	1110	34
2750	1080	39	2030	758	24
1990	699	21	1350	451	11
1370	343	8	920	266	4
920	229	2	733	186	0
648	148	1	566	121	2
491	97	0	437	83	2
477	69	0	356	82	1
396	56	1	362		
340	44	0			
315					

Table J-9. Environmental chamber, fan 100%, ionization off, RH = 85%, temperature = 80°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
2310	890	32	2090	757	21	1570	590	11	2310	970	28	1760	594	15
1390	298	7	1190	261	5	1010	271	3	1470	379	9	1020	227	4
814	156	4	774	109	0	684	72	1	847	148	1	681	106	1
508	55	1	538	51	1	380	35	0	537	75	0	475	30	0
393	21	0	392	23	0	369	9	0	454	38	0	415	30	1
312	27	0	337	20	0	266	13	0	332	28	0	404	16	3
323	21	0	286	11	0	224			298	15	0	301	12	0
245			237						258					
Run 6			Run 7			Run 8			Run 9			Run 10		
1770	730	26	1560	520	11	1600	640	12	2430	1000	39	3250	1140	13
1180	270	4	900	209	2	830	270	5	1690	431	12	1610	397	11
654	119	4	612	107	0	580	70	3	874	185	4	994	148	1
455	55	0	453	46	0	334	34	1	703	72	4	642	63	0
335	21	0	367	31	0	325	22	1	482	43	0	489	32	1
267	14	0	306	14	0	290			381	21	0	455	36	0
250	12	0	317	8	0				318	16	0	405	23	0
197			183						259					

Table J-10. Environmental chamber, fan 60%, ionization on, RH = 85%, temperature = 80°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
1080	360	24	1130	320	15	1620	490	8	1100	330	6	1100	350	4
578	167	11	625	221	4	888	284	3	583	235	2	638	210	1
366	114	3	410	129	4	615	185	2	412	148	3	378	145	0
292	48	0	266	77	1	331	98	2	233	68	2	308	85	0
155	29	1	133	42	0	200	46	1	194	53	1	165	57	0
						179	27	0						
Run 6			Run 7			Run 8			Run 9			Run 10		
1110	290	8	1350	425	15	1420	395	10	1600	502	18	1770	515	11
613	228	1	837	293	7	881	218	1	1023	309	3	1103	315	6
376	122	3	551	157	5	587	99	1	615	139	1	651	157	1
266	80	1	360	87	3	375	74	0	381	89	0	475	97	1
168	50	0	199	38	1	267	32	0	268	59	0	306	36	0
									174	38	0	225	32	0
												193	27	0

Table J-11. Environmental chamber, fans off, ionization on, RH = 85%, temperature = 80°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
2590	1680	187	2380	1310	41	2280	1300	16	2020	840	28	3440	1070	40
2240	1480	110	2020	630	25	1200	422	14	1790	723	12	2600	1390	47
2040	1110	102	1190	433	11	731	254	6	1223	514	9	1870	880	49
1560	885	60	747	256	4	584	182	4	810	327	6	1270	590	19
1230	646	37	572	169	6	432	110	1	579	201	2	695	288	7
978	449	27	416	110	1	310	77	2	361	126	2	403	173	1
717	326	17	307	64	2	221			316	106	2	323	78	3
494	249	19	243						274			215		
425	173	6												
272														

Run 6			Run 7			Run 8			Run 9			Run 10		
2330	1010	27	2060	710	15	2240	810	23	1500	723	15	3220	1050	97
1250	608	8	1180	534	8	1830	789	21	985	390	6	1800	851	57
712	286	2	383	388	5	1450	732	18	705	271	4	1310	546	36
604	188	2	558	235	1	1480	671	18	502	214	3	960	435	27
430	89	1	379	229	5	1020	479	11	388	113	2	694	313	26
360	68	0	339	189	3	775	247	5	328	92	1	548	227	10
207			204			559	259	3	252			417	185	5
						462	178	2				372	128	6
						380						254	90	4
												185		

Table J-12. Environmental chamber, fans 100%, ionization on, RH = 85%, temperature = 80°F. Each reading taken every three minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
2890	940	35	1416	473	10	1680	550	20	1565	464	2	1565	538	8
1200	220	9	587	122	3	750	143	1	608	132	1	713	134	1
440	59	0	190	41	0	264	59	0	235	42	0	285	46	0
177	20	0	105	20	0	117			122			133		
83	11	0												
Run 6			Run 7			Run 8			Run 9			Run 10		
2136	775	8	1220	347	3	1417	553	13	1302	534	11	2774	993	14
895	208	1	492	108	0	496	133	1	513	114	2	1193	239	3
349	41	0	193	27	0	202	34	1	195	38	0	403	61	0
165			105			112			97			189	11	0
												150		

Table J-13. Environmental chamber, fans off, ionization on, collectors on, RH = 50%, temperature = 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
7340	4280	372	8250	3200	141	7650	2710	123	7880	3180	104	10040	3940	130
7310	2040	153	4420	1500	65	4320	1340	39	4490	1650	41	5340	1880	77
3000	1000	58	2440	906	31	2260	732	15	2310	841	29	2440	940	35
1610	531	22	1170	444	7	930	372	3	1150	458	6	1360	415	7
949	295	11	698	198	5	524	157	5	578	207	3	737	167	10
494	172	3	390	121	2	277			321			361		
278			176											
Run 6			Run 7			Run 8			Run 9			Run 10		
5090	2030	134	8060	1440	13	10200	2050	17	11300	2240	16	12400	2330	20
3500	1240	100	1960	291	0	2390	454	4	2430	451	1	3120	421	0
2630	639	34	512	84	0	715	124	1	659	113	0	798	106	0
1010	439	15	229			222			247			266		
843	176	8												
338														
Run 11			Run 12											
10700	2080	12	11850	2360	13									
2370	428	0	2940	468	1									
650	90	0	784	125	1									
233			252											

Table J-14. Environmental chamber, fans 100%, ionization on, collector on, RH = 50%, temperature 50°F. Each reading taken every 3 minutes starting with 0.5μ

.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ	.5μ	2μ	5μ
Run 1			Run 2			Run 3			Run 4			Run 5		
3350	1390	77	3280	1400	46	2280	840	49	3220	1380	53	2250	890	53
2440	780	26	1320	802	17	1350	424	14	1770	781	29	1300	418	9
1220	398	19	1250	413	12	702	246	7	990	431	9	586	255	9
668	263	5	759	205	4	341	146	2	539	230	5	387	124	3
362	95	2	532	164	2	171			330	125	2	267		
212			425	101	1				177					
			291											

.5μ	2μ	5μ	.5μ	2μ	5μ
Run 6			Run 7		
3060	1910	91	2800	840	64
2310	1350	49	1360	408	5
1780	686	16	915	171	0
1130	417	15	469	75	0
597	214	3	308		
338	124	2			
263					

APPENDIX K: ION CONCENTRATION FOR VARIOUS LOCATIONS IN ENVIRONMENTAL CHAMBER

Table K-1. Ionization concentration in: Environmental chamber with fans off, measured in a grid pattern in planes parallel to the floor; the lower right corner is the southwest corner of the chamber. The point discharge is 10 in. above floor with needle pointing downward

Average height of probe above floor is 5.5 in.
(readings in millivolts)

65	110	150	180	160	115	80	90	140	180	180	150	100	75	50	38
80	150	245	300+	275	180	110	130	220	300+	300+	240	145	90	60	34
100	220	300+	300+	300+	265	160	180	300+	300+	300+	300+	200	115	70	30
110	200	300+	300+	300+	280	160	180	300+	300+	300+	300+	210	130	75	26
82	160	270	300+	300+	220	190	125	155	290	300+	300+	175	92	57	22
65	125	190	215	200	130	100	120	190	250	255	195	130	75	45	18
40	55	70	95	122	105	75	55	60	100	125	110	80	50	35	14
25	40	60	70	70	55	40	45	60	75	70	60	40	20	12	10
20	30	40	45	42	35	30	30	42	48	45	35	20	15	5	6
0	10	15	15	15	120	20	15	15	20	20	15	15	10	0	2 ↑
60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	←inches

Average height of probe above floor is 10.5 in.
(readings in millivolts)

50	110	175	205	190	140	100	95	145	200	200	160	120	70	30	38
100	200	300	300	300	230	140	150	265	300+	300+	300	185	110	50	34
125	260	300	300	300	300	170	195	300+	300+	300+	300+	240	125	50	30
130	250	300	300	300	300+	165	180	300+	300+	300+	300+	235	110	45	26
110	200	295	300+	300+	220	125	140	210	300+	300+	180	180	110	50	22
85	130	175	200	185	135	95	90	120	170	190	170	125	75	55	18
50	80	100	110	105	85	60	55	70	105	105	100	75	60	30	14
35	50	60	65	55	45	35	35	50	60	65	55	50	35	20	10
20	30	40	45	40	35	30	35	40	45	45	45	35	25	15	6
17	20	20	22	25	25	20	20	20	25	25	20	20	12	5	2 ↑
60	56	52	48	44	40	36	32	20	24	20	16	12	8	4	←inches

Average height of probe above floor is 24.5 in.
(reading in millivolts)

4	6	14	18	18	14	11	14	20	25	27	16	16	5	3	40
5	7	16	18	22	20	18	15	10	15	25	20	18	12	8	36
5	8	10	15	20	20	15	10	2	2	15	10	20	15	10	32
5	6	5	5	5	4	3	0	2	2	5	5	5	5	5	26
0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	22
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
															↑
60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	←inches